

OUR WORLD AND US

A. GOWANS WHYTE



THE WORLD
OF YOUTH
SERIES

IF YOU WERE GOING A LONG VOYAGE,

would you not be pleased to take with you a guide who could tell you something about the strange and delightful things that you would see from day to day—the men and women, the rocks and trees, the birds and beasts, the fishes in the sea?

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by MRS. AMABEL WILLIAMS-ELLIS.

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OUR WORLD AND US

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AN OLD PICTURE OF THE WORLD



This picture shows what people in the Middle Ages thought the world was like. The earth was supposed to be flat, and the sun, moon, and stars were supposed to be held on a bowl-like "firmament" over the earth. The old-time artist actually drew somebody peeping through the firmament into the other world.

The World of Youth Series, No. 5

OUR WORLD AND US

A SIMPLE ACCOUNT OF "HOW THE
WHEELS GO ROUND"—FROM THE
ELECTRON TO THE STAR

BY

ADAM GOWANS WHYTE, B.Sc.,

AUTHOR OF "THE WORLD'S WONDER STORIES," "THE
WONDER WORLD," "CHRISTABEL'S FAIRYLAND,"
ETC.

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AUTHOR'S PREFACE

IN this little book I have tried to tell, in the simplest possible language, what we ourselves are made of, and how the world around us and the heavens above us are built.

I take the reader on a double journey. *First*, among smaller and smaller things until we reach the atom and go past it to the electrons that whirl like tiny planets round the "sun" of the atom. *Second*, among the planets and stars to the furthest regions of space, where everything is just as unthinkably great as inside the atom it is unthinkably small.

Although I have written for children who are beginning to wonder "how the wheels go round," I hope the following pages will also serve to awaken the interest of older readers in the romantic story which modern science has to tell about men, matter, and the multitudes of stars.

New chapters are being added to this story year by year and almost month by month. Much that they have to tell us is novel and bewildering, especially to anybody not well up in mathematics. My purpose does not carry me so far as these more difficult chapters. It is limited to sketching a broad outline easily understood by the general reader and ready to be filled in by later study.

CONTENTS

CHAP.		PAGE
I.	WHAT ARE WE MADE OF? . . .	I
II.	MATTER IS "ALL ALIVE" . . .	17
III.	INTRODUCING THE ELEMENT FAMILY .	32
IV.	WHAT IS INSIDE THE ATOM? . . .	50
V.	EVERYTHING MADE OF ELECTRICITY .	63
VI.	THE SUN AND PLANET FAMILY . . .	72
VII.	WHAT ARE THE STARS MADE OF? .	88
VIII.	MYSTERIES OF THE MILKY WAY .	102
IX.	HOW STARS ARE BORN	115
X.	HOW WAS THE SUN AND PLANET FAMILY MADE?	130

LIST OF FULL-PAGE ILLUSTRATIONS

THE WORLD AS CONCEIVED IN THE MIDDLE AGES	<i>Frontispiece</i>
<i>Reproduced from Bürgel's "Astronomy for All" by kind permission of Messrs. Cassell & Co., Limited.</i>	

FAMILY LIKENESSES AMONG THE ELEMENTS .	PAGE 36
PART OF THE MILKY WAY	III
THE GREAT NEBULA IN ANDROMEDA . . .	II7
* VARIOUS TYPES OF NEBULÆ.	127

* These illustrations, together with those on pp. 106 and 138, are reproduced from "The Universe Around Us" (Sir James Jeans, M.A., D.Sc., LL.D., F.R.S.) by kind permission of the Cambridge University Press.

CHAPTER I

WHAT ARE WE MADE OF?

ONE of the silliest nursery rhymes I know is this :—

What are little boys made of?
Frogs and snails,
And puppy-dogs' tails—
That's what little boys are made of !

What are little girls made of?
Sugar and spice,
And all that's nice—
That's what little girls are made of !

I never liked this rhyme. I felt it was not quite fair to boys. As for girls—well, every girl knows some other girl who is not just sugar and spice and all that's nice.

What I disliked most about it, however, was that it dodged a very interesting and puzzling question. I know, of course, that

nursery rhymes are not intended to answer solemn questions. They are just amusing jingles, with next to no meaning at all. But as boys and girls always begin sooner or later to ask such questions as "Where do we come from?" and "What are we made of?" it would be a great relief to them and their parents if the questions could be answered by a few easy nursery rhymes.

I can remember the time when I thought that the question, "What are we made of?" could never be really answered. I had learned a little chemistry and could understand how it was possible to tell whether, say, a white powder was common salt or chalk or something else. One had only to test it with acids and in other ways to find out by its behaviour what it was. That sort of thing was easy—much easier than finding out what our skin was made of.

To begin with, skin was *alive*. It wasn't stuff made in a factory or a laboratory and sold in a labelled bottle. Like our blood and our bones, it was something that *just*

grew, and I was quite sure that not even the wisest man in the world, no matter how clever he was with powders and liquids and other "dead" things, could tell me what had gone to the making of the wonderful, mysterious things that made up *me*.

About this time I was very fond of a guessing game called "Animal, Vegetable, and Mineral." Somebody thought of something—a rose, a cricket bat, a piece of barley-sugar—and the others had to guess what it was by asking questions which always began with "Is it animal?" "Is it mineral?" "Is it vegetable?" We had not the slightest doubt that everything in the world was either one or the other. Not for many years afterwards did I learn that there are some living things so simple—mere tiny blobs floating in water—that no one can say whether they are animal or vegetable. Not for a long time, too, did I discover that there was any connection at all between the "animal" or "vegetable" and the "mineral." I thought they were as different "as chalk from cheese." Indeed,

so very different that nothing in the one could be found in the other.

If I had thought very much about the matter I might have suspected that I was wrong. I might have seen that, since both the "animal" and the "vegetable" live on the "mineral," the three must have a good deal in common, and must be, as we might say, related to each other.

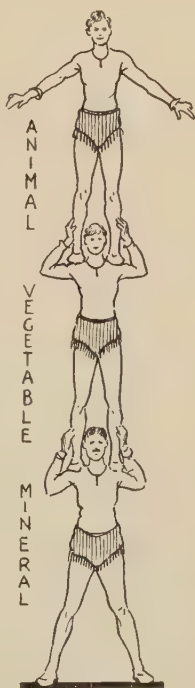
Like most healthy boys, I ate, and ate heartily, without thinking about where the food came from, or about the wonderful things that happened to it after I swallowed it. I suppose I had a hazy kind of notion that the bread and beef I ate, and the milk I drank, became part of me; but as this was an everyday marvel, I paid little heed to it. As a wise man said, if the sun set once in a hundred years instead of every day, the whole world would talk about it for years before and years after the amazing event.

Milk is what is called "a complete food." It contains pretty well everything we actually need to build flesh, bone, and

blood. We get our milk from the cow. The cow makes it from the grass it eats. The grass in turn lives and grows on sunlight, air, and the "minerals" it draws, along with water, through its roots. So in the long run we animals build ourselves out of "minerals." Living creatures, in short, live on things that are not living.

If you wanted to make a picture of this you might take as your model the acrobats in the circus who stand on each other's shoulders.

The first acrobat is the "mineral." The one standing on his shoulders is the "vegetable." The third, standing on the shoulders of the second, is the "animal."



A pictorial reminder of how the animal world depends on the vegetable, and the vegetable world on the mineral.

This is something like the old fable that the earth was carried on the back of a giant named Atlas, who stood on an elephant, which stood on a tortoise. Nobody, I believe, worried about what the tortoise stood on, but if you asked me what the "mineral" in our picture is standing on I would answer, *On the sun*. It is sunshine, with its light and heat, that keeps things going on the earth.

Now we have got what the detectives call "a master clue" to the question, "What are we made of?" As we are "made of" the food we eat, and as our food comes from "minerals," we ourselves must be built up out of "minerals."

Suppose we made a list of all the minerals—that is to say, all the things that make up the soil, the sea, the air (and the sun and stars as well!)—we should find that in this list are all the things found in our brain, bone, blood, muscle, skin, hair, and the rest of us.

We can put this to the test by "pulling

ourselves to pieces " to see what we are made of. When a chemistry class is given a powder to "analyse," it sets to work to pull the stuff to pieces with heat, acids, or something else. For example, if the powder is chalk, the class will break it up into lime and carbon dioxide. It may go further and break the lime up into calcium and oxygen, and the carbon dioxide into carbon and oxygen. Beyond that point it cannot go, because calcium, carbon, and oxygen are what are called "elements." Nothing simpler is known. We might go on pulling calcium to pieces for ever without getting anything but calcium.

What happens if we "analyse" our bodies in the same sort of way?

The first thing we find out is likely to give you a shock. When Hamlet said, "O that this too, too solid flesh would melt," he would, I think, have been very much surprised to hear that it was not solid at all. Two-thirds of Hamlet's weight was due to *water*. Shakespeare tells us that Hamlet was fat, so we may take it that he

weighed at least twelve stone. Only four stone in his plump body was solid. The rest was water.

In your grandfather's time a great man, Thomas Carlyle, wrote, in a moment of bad temper, that there were forty million people in England—"mostly fools." He would have been more truthful, as well as more polite, if he had said "mostly water."

Now, perhaps, you will understand why it is that a man can keep alive for three weeks or more on water alone, but will die in a few days if he cannot get water. The "fasting men," who used to be found with the Fat Lady, the Wild Man of Borneo, and other freaks in country fairs, always had their regular drinks of water.

The great part that water takes in our bodies is not just a "freak of nature." It has a meaning, and a very interesting one.

In another book ¹ I described how the very first living things began *in water*. They were just tiny specks in water. For a long,

¹ *The Wonder World*.

long time—millions of years, perhaps—during the childhood of the world, there was no animal life at all outside the lakes, rivers, and seas. Then came a period when animals “came ashore,” as it were, and contrived to live in air. The fish stage was followed by the reptile stage, and later the procession of life advanced to higher and still higher forms until man himself appeared.

So, in a sense, we human beings, like all other animals, were born in water. We were “rocked in the cradle of the deep” millions and millions of years ago. If our bodies could not get “common salt”—which is the salt of the sea—we would die. Every time we read of animals walking miles to a “salt-lick” we are reminded that the animals had their first home in the sea. Every time we say “Pass the salt” at the dinner table, we are reminded that we are related to the animals.

It is not surprising, therefore, that our bodies are full of water. As one writer has put it, “all organisms live in running water.”

I have already taken you a long way towards answering our question. We are, for the most part, made of water. And as water is made up of two gases, hydrogen and oxygen, we can say that human beings are largely made up of the two gases which, when united by an electric spark, form water !

There are other gases in our bodies—gases “on their own,” and not united to make liquids or solids. Every time we breathe we take air (a mixture of oxygen and nitrogen) into our lungs. The oxygen purifies our blood and becomes carbon dioxide, which we “breathe out.”

Not only do we carry gases around with us in “gas-bags” such as our lungs. Gases soak themselves into our blood. For example, some of the nitrogen we breathe gets into our blood—a fact which deep-sea divers found to their cost. When a diver goes down he breathes compressed air, which is pumped in to him through a tube. He gets far more nitrogen than usual into his system. His blood, in fact, becomes

“charged” with nitrogen, just as a soda-water syphon is charged with “fizz”—that is to say, with carbonic acid gas. If he is brought to the surface quickly, bubbles form in his body, much as they do when you press the lever of the syphon and make the soda-water fizz. These bubbles cause terrible pain, and in bad cases bring on life-long illness.

The only way to prevent the bubbles forming is to bring the diver up by very slow stages, so as to give plenty of time for the gas to ooze harmlessly out of his body.

When we come to the “too-too solid” parts of our bodies, it is not so easy to describe what they are made of. Our bones are perhaps the simplest items on the list. They are chiefly made up of a hard substance called *calcium phosphate*, which in turn is made up of calcium, phosphorus, and oxygen.

The rest of us—our flesh, heart, stomach, liver, skin, and so on—shows such a bewildering variety of things that we might

well give up the attempt to find out exactly what is in each one of them. Doctors spend years in learning how each part of our body's machinery works, and the wisest men are still a long way from knowing all they want to know about the ins and outs of our insides. All the same, the chemist can tell us the names of the "elements" out of which this puzzling machinery is built. They are quite common, familiar ones—chiefly carbon, oxygen, hydrogen, nitrogen, phosphorus, and sulphur.

In addition, our bodies contain a little sodium and chlorine (which go together to make salt), potassium, fluorine, iron (which colours our blood red), magnesium, iodine, lithium, and silicon. Tiny quantities—which the chemist calls "traces"—are also found of some metals—lead, copper, and manganese.

This list of "hard words" may frighten you if you are not well up in chemistry, and have not got used to talking about fluorine, silicon, oxygen, and so forth. But I do not

think you should find it frightening at all. The amazing thing is that it is such a short list of ordinary things.

There are altogether *ninety* elements known to us to-day, most of them very rare. Two others are thought to exist, but have not yet been discovered. Only about one out of five—and quite common ones—have been used to make *us*. *You will find in a "strike-anywhere" match pretty well everything that is inside our bodies.*

I have come across two amusing "inventories" of the human body. "Inventory" is a big word for a very simple thing. When a house is being "let furnished" a list of the things inside it is drawn up, so that the new tenant will know what he is paying for and also what he must hand back in good order when he leaves the house. Such a list is called an "inventory."

Oliver Wendell Holmes, an American writer who was well known in your father's and grandfather's time, but is almost forgotten to-day, made this short inventory :—

“A few gallons of water, a few pounds of carbon and lime, some cubic feet of air, an ounce or two of phosphorus, a few drams of iron, a dash of common salt, a pinch of sulphur, and a grain or more of each of several hardly essential ingredients, and we have man. . . .”

I take a fuller inventory from Dr. Ronald Macfie, who tells us that the body of a woman (smaller than a man) contains all these :—

Nine gallons of water.

Eight hundred nine-gallon bottles of oxygen.

Enough carbon to make 9000 lead pencils.

Enough phosphorus for 8000 boxes of matches.

Enough hydrogen to fill a balloon able to rise to the top of Snowdon.

Iron for five tacks.

Salt to fill six ordinary salt cellars.

Five pounds of nitrogen.

This list of articles is not much more impressive than mother's shopping list. It may give you a feeling that we are not such wonderful creatures, after all, if we are made of the same sort of stuff as lead pencils, tacks, and matches.

On the other hand, it may give you a hint that common "stuff" is really wonderful beyond description. For man, who is made out of this common stuff, has learned a lot about that same stuff. He has traced his own history back to the far-far-off times when life began; he has weighed the world he lives on, and the planets, and the sun, and even the distant stars. He has learned how these bodies move in the vastness of space; what they are made of, and whether they are hot or cold. He has "changed the face of the earth" with his roads and canals and bridges and his agriculture. He has invented ways of using coal and waterfalls and electricity and a million other things. He can send a message round the world in a flash; he can talk across thousands of miles. He has composed beautiful

music, painted lovely pictures, and written wise and wonderful books. . . .

There is no end to the wonders of man. I could go on with the story for hours without getting half-way through the first chapter. When you think of all that man has done with his brain and his hands, you will begin to see that the "matter" out of which he is made deserves to be treated with respect.

In the next chapter we shall go hunting to find out, if we can, what matter is made of. Meanwhile let us look back on what we have learned about ourselves :—

Everything used to be divided into "animal," "vegetable," and "mineral."

Animals live on vegetables, which in turn live on "minerals." So we are built out of "minerals."

Two-thirds of our bodies consist of water.

Our bones, blood, and flesh are made up of about nineteen of the most common "elements" out of the ninety known to us.

CHAPTER II

MATTER IS "ALL ALIVE"

IT takes some time to get over the surprise of finding that the "lords of creation" are made of the same stuff as we get in the sea, the soil, plants, and the "lower animals." I well remember how huffed I was when, as a small boy, somebody who had a "book of names" told me that my first name, Adam, meant "Red Earth."

I was not in the least consoled when I was reminded that in the Bible story Adam himself was made from the earth. Whatever the first man might have been, I thought I was a long way above that.

But, after all, such vanity is silly. Nothing in this world is really "common." A grain of sand is just as wonderful in its way as a star. I am not "drawing the

long bow " when I say that you could spend your whole life trying to learn how a grain of sand is made, and at the end, even though you were an expert in chemistry, electricity, mathematics, and all the rest of the " high-brow " things, you would feel that you had still far more to find out than you had yet discovered.

Take the " commonest " thing in the world—water. Pass electricity through a bowl of water, and you split the water up into two gases—hydrogen and oxygen. Mix these two gases and make an electric spark in the mixture, and the gases form water again.

Quite simple ! You learn this at the very beginning of your chemistry lessons at school. Yet what a marvel it is that two gases combine to form a liquid which behaves altogether differently from either of the gases. Hydrogen burns. Oxygen makes things burn. Water is used to put fires out !

The way new things are " created " by uniting other things is astonishing. Water

is made up of two parts of hydrogen and one part of oxygen. When we combine two parts of hydrogen with *two* of oxygen, we get something new—a liquid used for cleansing wounds or making dark hair turn golden. Boy Scouts and Girl Guides use this "Peroxide" for "first aid" when they are cut or scratched. There is some of this half-cousin of water in the "Peroxide" tooth paste which perhaps you use to kill the microbes that eat away your teeth.

Again, one part of charcoal and one part of oxygen make a gas which is a deadly poison. Add another part of oxygen, and we get the carbon dioxide which is in the air we breathe.

These are only one or two simple examples out of a great multitude. When chemists play about with just a few "common" elements like carbon, hydrogen, and oxygen in different ways, they get an almost endless crowd of things, all distinct from each other.

You can get some idea of how this comes about by thinking of the alphabet. There

are only twenty-six letters in the alphabet ; and out of these we have made thousands upon thousands of words, and by stringing these words in different ways we can make tens upon tens of thousands of sentences—all distinct from each other.

It is much the same with music. There are only 85 notes on the piano, but for centuries composers have been giving us new pieces to play, and they are likely to go on for centuries more without repeating themselves.

When you think over these wonders—which we are so used to that we do not realize how wonderful they are—you will perhaps begin to understand how it is that we ourselves have been built up of a few familiar elements.

The simplest kind of living stuff is called "protoplasm." I have always liked the sound of that word so much that I took to it before I knew what it meant. It means "first formed." Every living thing, from the tiny single-cell "amoeba" floating in

water up to man himself, is built of protoplasm.

Protoplasm is "alive." It can take in food, digest it, grow, and reproduce itself by dividing up. Anything able to do all that is, as you can imagine, far from simple in its make-up. So we need not be surprised to find that protoplasm contains 400 parts of carbon, 120 of oxygen, 310 of hydrogen, 50 of nitrogen, 2 of sulphur, and 2 of phosphorus.

Nothing that a chemist has been able to make is nearly so elaborate as that. Some day one of our clever chemists may be able to manage it—to build up these elements in his laboratory as Nature did in its laboratory millions of years ago. But, whether he will ever succeed or not, the marvels that chemists have produced with a few simple "compounds" make it easy for us to understand how a far from simple thing like protoplasm can behave in the very special way we call "living."

It is not easy, I know, to get used to the

notion that "living" stuff can ever be built up out of "dead" stuff. We feel about that sort of notion much as I thought about the mystery of skin—I was so sure that never, never could we ever find out what skin was made of. Living things are so different!

Until about one hundred years ago, everybody was agreed that "living" things were in quite another world from "dead" things. Chemists talked about "inorganic" chemistry and "organic" chemistry. "Inorganic" meant that the things could be made in the laboratory. "Organic" meant that we could get them only from living animals or plants—as, for example, bees make honey, and flowers make the nectar out of which the bees make the honey.

Little by little, however, chemists found out that they could make all sorts of "organic" things without calling upon an animal or a plant to help them. Every time they did the trick they built a bridge, as it were, between the "inorganic" and

the "organic" worlds, between the "dead" stuff and the "living" stuff.

I need give you only one example, although I could mention thousands of them. Our blue-jackets' clothes used to be dyed "navy blue" with a dye called "indigo," which we got from a plant grown in India. Up to about forty years ago, most people would have laughed at the thought of so wonderful a dye being made in a factory. But in 1897 "made" indigo appeared on the market and won a very quick conquest over the "natural" indigo. Man, in short, had gone one better than Nature!

If you are learning "stinks" at school, you will very likely know that the subject of chemistry is still divided into "organic" and "inorganic." But "organic" chemistry does not mean to-day what it meant a hundred years ago. It just means the "chemistry of the carbon compounds." Carbon (which we know better as charcoal, lamp-black, "lead"—for "lead" pencils—and diamond) is always found in living

stuff. Our "organic" chemists, however, have made it up into thousands of things—dyes, medicines, and so on—that were never known before.

What is all this leading up to? It is leading up to the thought that everything in the world—we ourselves, the animals, the plants, the air, the rocks, the sea—belong to *one* world and are made up in different sorts of ways from the same sort of stuff.

The more we learn about this "stuff," the less strange this thought will become. For this world-stuff, which we call "matter," becomes more and more wonderful the more we examine it. A great deal has been learned about it within the last fifty or so years, and every new discovery makes us take off our hats once more to the marvels of matter.

Our grandparents were inclined to look upon matter as really *dead* stuff. Matter, they thought, could do nothing unless it was pushed or pulled by some force. What force was nobody really knew; but the

word was a handy one to describe what seemed to happen. Thus "chemical force" made hydrogen and oxygen unite to form water. "Electrical force" drove a current through a wire. The "force of gravity" pulled an apple to the earth and held the earth in its course round the sun. And so on.

I am not going to weary you with a long talk about these mysteries. All I want to do is to show you that matter is not so lazy as it was once made out to be. It does not need a whip to force it to be up and doing. As a matter of fact, matter is never *at rest* anywhere for a single instant.

I well remember how surprised I was when a teacher told us of an experiment with two metals. Nothing, you might well say, is more solid, more "dead," than a piece of gold or a piece of lead. "Dull as a lump of lead" is a very expressive phrase. But when two pieces of such metals were pressed together and kept so for a few years, particles of the gold wormed their way into the lead. In this way "dead" metals will,

if they are given plenty of time, *mix* in much the same way as lemon syrup and water will mix when stirred (or "forced") by a spoon.

So you get the notion that the particles of the metal were not at rest, but were on the move all the time.

Imagine two sets of schoolboys, one set wearing blue caps and the other set red caps, side by side in the crowd at a football match. At the start the blue caps are all together and the red caps all together, jammed in the crowd so tightly that they seem hardly able to move. In the excitement of watching the play, however, the boys will jostle each other, and by and by a few of the blue caps will be found among the red caps, and *vice versa*.

That gives you a kind of picture of what seems to happen when two metals are pressed against each other. Just as the boys would not get mixed if they were really quite still, so the particles of metal would not get mixed if they were truly at rest.

Now let us turn to liquids, where something no less astonishing is to be discovered.

If it is possible for the particles of a solid metal to be on the fidget, it seems still more possible for the particles of a liquid to keep moving, since a liquid is itself so easily moved.

This is what actually happens. The discovery was made about a hundred years ago, but it was then looked upon as a mere curiosity, without any particular meaning.

A botanist of the name of Brown was looking through the microscope at some sap in which tiny specks were floating. Brown noticed that the specks were on the move all the time—dodging backwards and forwards as if jostled by some unseen but very busy "forces."

This movement was called the "Brownian" movement, after its discoverer. Years passed, however, before the freak was explained. The jostling was done by the particles of the liquid itself, which were always on the go and pushed the tiny grains backwards and forwards as the waves of a

stormy sea toss a boat. While the liquid seemed to be perfectly still, it was really throbbing with motion. It was, in its way, "alive." Thanks to the floating specks, we can see the effect of the ceaseless fidgeting of the particles of the liquid, although the particles themselves are too small to be seen even in the most powerful microscope.

Strange as it may seem, this fidgeting explains what happens when water dries up.

The big word for drying up is "evaporates," which means changing into a vapour or gas. I am afraid that when I was a boy I used to take this change for granted, without thinking very much how it happened. I just thought it was a habit of water and other liquids to change into vapour, and I left it at that!

The change is, however, quite easily explained. With the particles of water always dashing about, those on the surface of the water have a chance of escaping into the air. They will be something like waves

which, if they dash high enough, get swept away in the air as spray. As the particles fly into the air and get carried off, the water gets less and less and the water vapour in the air more and more.

If we heat the water, we set the particles dashing about more wildly than before, so that they escape quicker from the surface. If we blow over the water, we help the surface particles to escape. That is why a day on which the sun is shining brightly and a strong wind is blowing makes what your mother calls "a splendid drying day."

Some liquids dry up, or evaporate, much more quickly than others. If we leave the stopper out of a tin of petrol for a few minutes, the vapour will have spread all over the room. We cannot see the vapour, but it is there, as we quickly find out if there is a naked light in the room. The vapour catches fire in a flash. That is why smoking is strictly forbidden in any place where petrol is being handled.

What happens in such cases? Simply

that the petrol particles are so active that they escape in crowds from the liquid and go dashing about in the air, spreading further and further every instant. In a gas or vapour the particles have far more room to move than in a liquid, and still more than in a solid. They dash backwards and forwards at a tremendous pace, colliding with each other and with any object that comes in their way.

There is really no such thing as "still air." On the stillest day the particles of air are bombarding our faces with the speed of bullets. We may be thankful that the particles are so very very tiny that we do not feel them hammering at us.

It may seem queer to you at first to think of all this excitement going on around us, unseen and unnoticed. It may seem still more queer to think that it is this bombardment by millions of tiny particles of gas that keeps our toy balloons "blown up," that moves the piston in a steam engine, that causes what are called explosions. But you will soon get used to the

notion that the particles of matter are always "on the go" in solids, in liquids, and still more in gases. Once you have got that notion into your head you will understand many things which would be very puzzling if matter was supposed to be so lazy, so "dead," that it had to be forced to do anything at all.

Here are some of the things we have learned in this Chapter:—

Ordinary matter is really very extraordinary.

"Living" matter and "dead" matter are made out of the same things.

"Dead" matter is not actually dead. Even in solid things like metals, particles are always on the move. In liquids they move more freely, and in gases they dash about with the speed of bullets.

CHAPTER III

INTRODUCING THE ELEMENT FAMILY

I SHALL have something to say later on the size of these particles I have been talking about, and also on how *they* are made up. In this Chapter I want to get back to the ninety-two "elements" out of which things are made.

An element, as you know, is something that the chemist cannot split up into anything simpler. Elements combine to make all sorts of different things; they are the bricks out of which everything on earth, dead or alive, and everything in the sun and stars, has been built.

Why are there ninety-two of these bricks?

You may reply that ninety-two bricks are not too many to build this world, which is "so full of a number of things." I agree. Just to glance at the crowds and crowds of

different objects in earth, air, and sky is enough to make us feel that nine hundred thousand bricks would not be too many. But we are up against the curious fact that most of the elements we have already found are very scarce. There may, of course, be other elements yet to be discovered, in addition to the odd two I have already spoken about. However that may be, the world that we know is mostly made up of quite a few bricks, while others are used very sparingly.

This is very curious. Every step we take down to the root of things seems to make the world *simpler*.

Another curious thing is that *the bricks are not altogether different from each other*. If we put them in a line, in order of weight, starting with hydrogen, which is the lightest, at one end, and putting the heavy ones, like lead and radium, at the other end, we find that at regular intervals along the line certain elements have a kind of family likeness to each other.

It would only confuse you if I put all

Helium	Lithium	Beryllium	Boron	Carbon	Nitrogen	Oxygen	Fluorine
Neon	Sodium	Magnesium	Aluminium	Silicon	Phosphorus	Sulphur	Chlorine
Argon	Potassium	Calcium	Scandium	Titanium	Vanadium	Chromium	Manganese

the ninety known elements “on parade” at the same time, so I shall take a couple of dozen of them. When we call the roll they answer to the following names:—Helium, lithium, beryllium, boron, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminium, silicon, phosphorus, sulphur, chlorine, argon, potassium, calcium, scandium, titanium, vanadium, chromium, manganese.

Some of these you perhaps never heard of before, because, as I mentioned above, they are very rare. Others are old familiar friends.

Now, if we parade these elements in the same order of weight, but in ranks of eight, we get them as shown at the side.

The elements in the first up-and-down row—helium, neon, and argon—are alike in being very “unsociable.” They refuse to combine with other elements. Lithium,

sodium, and potassium, again, are alike—if not as much alike as three peas, at least as much as three brothers. In all the other up-and-down rows the elements have their likenesses, and if we were to complete the parade for all the elements we should find the same sort of family arrangement going in an almost regular way from top to bottom.

When these family likenesses were first discovered—by a Russian chemist, named Mendeleéff, about the year 1870—there were many blanks in the ranks. Some of the elements had not turned up on parade. Mendeleéff was able to foretell, however, in several cases what the missing elements would be like. In a few years' time chemists discovered elements exactly as Mendeleéff said they would be. Scandium (you will find it in the fourth up-and-down row) was one of these elements, which, romantically enough, had its portrait painted years before anybody ever saw it.

The family groups among the elements remind one of the family groups among

							
Helium	Lithium	Beryllium	Boron	Carbon	Nitrogen	Oxygen	Fluorine
							
Neon	Sodium	Magnesium	Aluminium	Silicon	Phosphorous	Sulphur	Chlorine
							
Argon	Potassium	Calcium	Scandium	Titanium	Vanadium	Chromium	Manganese

These figures, named after twenty-four of the elements, give a fanciful picture of the "family likenesses" shown among the elements when they are paraded in order of weight. It will be noticed that the figures in up-and-down rows have something alike in them. These likenesses are a reminder that all the elements are made out of the same stuff and form one big family.

animals. Birds, fishes, insects, reptiles, mammals, and so on, are groups made up of animals which have a kind of family resemblance to each other. In the case of animals we are lucky in having a storehouse, in the rocks, of remains of animals which lived hundreds and thousands of years ago. From these remains, called "fossils," we can tell the history of the different families, and this history shows us that all the various families came from the simplest animals which appeared at the very dawn of life. In short, all the families of animals are *one family*.¹

This notion of the "evolution of animals" came as a great shock to our grandfathers. They had got so used to looking on every family of animals as specially made to a special pattern that they could hardly believe in living things changing in different directions until they had produced several distinct families. But nowadays we are quite used to the "family tree" of animals, and when we see family likenesses running

¹ See *The Wonder World*.

through the elements we begin to suspect that there may be something like a "family tree" of elements as well.

Close on a hundred years ago it was hinted that all the elements might be built up out of one substance. Instead of ninety quite distinct and separate elements, there might just be ninety different forms of the one element.

Does this idea of the world being made out of one kind of stuff startle you? I expect it does. I can almost hear you say, "Stuff and nonsense," to it. All the same, I warn you that there are other surprises in store for you, which will startle you still more.

Before I let them loose on you I must keep my promise to say something about the size of the particles out of which all the elements, whether they are different or alike, are built up. This may appear to be taking you right out of the track we have been following, but you will find that we are not losing our way in the least.

Suppose we go on dividing a drop of water

into smaller and smaller bits until we cannot possibly divide it any more. I have called this smallest possible bit of water a particle, but the right name for it, as used by chemists, is "molecule." A "molecule" is the smallest portion of any substance that can combine with any other substance. Anything smaller than a molecule of water would not be water.

Next, let us split one molecule of water into the gases which unite to form water—hydrogen and oxygen. Hydrogen and oxygen are elements. They cannot be split up into anything simpler. And the smallest possible bit of an element is called an *atom*.

Atom means something that cannot be divided. The atoms are the grains out of which the "bricks" which make the world have been built up. They are so frightfully small that we can really form no picture in our minds of how small they are.

Tiniest of the tiny though they be, we can both measure them and weigh them. An atom of hydrogen is about as much smaller

than a tennis ball as the ball is smaller than the earth. An atom of hydrogen is as much lighter than a small pellet of shot for a gun as the pellet is lighter than the whole earth.

Here is another attempt to give us some idea how small the atoms are. If people could count atoms at the rate of a hundred a minute, and if you had two thousand million people counting at that rate, they would need one hundred million years to count the atoms in an ounce of hydrogen.

Or take an ounce of lead. The lead atoms are much heavier than the hydrogen atoms, so not so many are needed to make an ounce. Yet in the ounce of lead there are *eighty thousand million million million atoms!*

If you put one hundred million atoms in a line, the line would measure just about one inch.

There are about 1850 million people in the world. You would need to put about as many atoms together before you would get

anything big enough to be seen under the most powerful microscope.

After you have amused yourself thinking about these "unthinkable" smallnesses, you will be ready to say that the atom is quite the smallest thing that ever could be. It seems to be "the limit."

Until about the year 1895 most people thought that the atom really was the limit—that it could never be cut up any smaller. "Once an atom, always an atom," seemed to be the rule. Also, "once a hydrogen atom, always a hydrogen atom," was looked upon as a rule. Atoms of any one thing, like hydrogen, or oxygen, or gold, were supposed never to change in any way at all.

The alchemists of ancient days, however, did not think so. They were always on the look-out for "the Philosopher's Stone," which would change one thing into another. Some of them pretended they could change copper into gold. They even offered to sell their secret, although you might well

wonder how anybody would be silly enough to pay money to a man who said he knew how to make as much gold as ever he wanted out of some cheap metal like copper.

We know that the alchemists were humbugs, or at least could never have done what they hoped to do. All the same, the alchemists were prophets of a sort. The change from one element to another has actually come about, although not in the way they dreamed.

If you look at a complete list of elements in a chemistry book, you will find that the three heaviest are radium, thorium, and uranium—the last being the heaviest of all. An atom of uranium weighs about 239 times as much as an atom of hydrogen. So heavy is it, in fact, that you might say it is top-heavy.

Now, in 1896 an extraordinary thing was discovered—almost by accident—about this Fat Boy of the Table of Elements.

Some photographic plates were found to

be "exposed," although no light had been allowed to get at them. There seemed to be magic at work. The French Professor, Henri Becquerel, who found this happen, must have been as much surprised as you would be if you managed to get a snapshot of a black cat on a pitch-dark night.

The clue to the mystery lay in some uranium which was lying near the plates. Professor Becquerel began making experiments with the uranium, and he found that it was shooting out invisible rays which were able to go through wood and paper and "expose" a plate or film just as if they were rays of light falling on an uncovered plate.

This discovery made as much noise in the scientific world of 1896 as Christopher Columbus's discovery of the New World did in the Old World of 1497. It was indeed, as we shall see, the discovery of a new world—the world of the atom itself.

What were these mysterious rays? Careful tests showed that there was more than

one kind. It is not easy for me to explain to you exactly what each kind was, without using a lot of "hard" words; but I shall try to give you some idea of two of them.

One was a stream of "specks of electricity," travelling at a rate twenty-one times lower than the speed of light. The electricity in this "ray" was positive electricity.

Another was a stream of "specks of electricity," travelling at a speed very near to that of light (186,000 miles per second). In this case the electricity was of the negative kind.

Nowadays, when nearly every home has its wireless, even the babies have probably heard about "positive" and "negative" electricity. These are the names given to the two different sorts of electricity, and all you need to remember about them for my purpose is that the two sorts are always trying to balance each other. In the ordinary way the things around us—the pen I am writing with, the table I am writing

on, the walls of the room in which I sit—are not “electrified,” because the positive and negative electricities in them are balanced. Anything is said to be electrified when it has more positive than negative electricity in it, or the other way about.

To say that the uranium gave off a stream of specks of electricity is, of course, not to explain the mystery. It is rather to deepen it.

How came the uranium to produce these “rays”? The thing never stopped. It went on night and day, and, no matter how the uranium was heated or cooled, it went on just the same.

Some light was thrown on the mystery when it was found that the uranium, in giving off its rays, changed into other things. One of these other things was *radium*, which you must have heard of as a precious substance used in curing dangerous growths in our bodies. Mme. Curie discovered radium in 1898, and as it proved to be much more active than uranium in giving off rays you

can understand how it got its name of radium.

Radium, like uranium, changes into other things. One of them is called polonium. Another is more familiar to us under the name of *lead* !

If the ghost of an ancient alchemist had been present when Professor Becquerel and Mme. Curie were doing their wonderful experiments, he might well have given a wild whoop and cried, "I told you so !" For here, without a doubt, was one element changing into another.

The change, however, was a very different thing from changing a farthing into a sovereign. Every change that uranium and radium make is into *something lighter*. They lose weight in making the change, while the alchemist's dream was to turn copper or bronze into gold, which is much heavier.

This difference gives us another clue which brings us near the heart of the mystery.

Just think again, for a moment, about what happens to these extra-heavy elements. They pour out electricity in "rays" and become lighter. That is to say, their atoms—the atom of uranium and the atom of radium—lose electricity and lose weight at the same time.

This shows, I think you will agree, that the atoms have "specks of electricity" inside them. They are not solid uncuttable bits of matter. They are not "the limit." They can be broken up; and when they break up, as they do in uranium and radium, they throw off some of the electrical particles out of which they are built. The "rays" are simply streams of fragments from a bursting atom.

This is one of the startling surprises I promised you, and I hope you are duly startled and surprised. In the next Chapter I want to tell you what has been learned about the inside of the atom, and about how one atom differs from another. Remembering how tiny the atom itself is, you might

think it impossible to learn anything at all about its architecture. Nevertheless we have learned quite a lot, and what we have learned helps us to understand the curious way family likenesses keep popping up among the elements.

As this has been a very “meaty” Chapter, I had better go back over the things it contains :—

Ninety elements have been discovered, most of them rather scarce.

There are “family likenesses” among the elements, just as there are among living things.

The “tree of life,” which shows all living things to be descended from the simplest forms of life, suggests that all the elements are formed out of some simple form of matter.

The tiniest particles of the elements, known as atoms, are so small that 100,000,000 in a line would measure no more than an inch.

These atoms were once supposed to be

quite distinct and never to change, but some years ago it was found that the heaviest atoms broke up and formed lighter atoms.

In breaking up, these atoms gave off electricity.

CHAPTER IV

WHAT IS INSIDE THE ATOM?

EVERY atom is a world in itself. Indeed, it is much more than a world. It is a kind of "solar system."

Later on we shall take a close look at the solar system, but for the moment all I want to say about it is to remind you that the planets, of which our earth is one, revolve round a sun which is ever so much heavier than all the planets put together. The picture we now get of the atom is very much the same. It shows a heavy "sun" in the centre, and round it are spinning a number of ever-so-light "planets." In some atoms there are very few "planets"; in others there are many more. There are most of all in radium and the other heavy atoms that are apt to "burst."

I hope you will remember that this is

only a picture. We can see the real sun and the planets quite clearly with our "naked" eyes or through a telescope. But the atom, as you know, is so frightfully tiny that it can never be seen. Its "sun" is so much more tiny even than the atom that you would have to divide an inch into one million parts, and divide each part again into one million to get near to the size of it. As for the atom's planets, which I have called "specks of electricity," they are simply too small for words.

When our wise men get to know more about the inside of the atom they will perhaps give us another picture which may be nearer the real thing. Indeed, some of them have already sketched a different picture, but it is such a difficult one that you would need a lot of "maths" to understand it. The sun and planet picture will do very well as a beginning, for it helps us to get away from the old notion that the atom is a solid grain. It gives us a useful "working model" of the atom.

To my mind, the most amazing thing about this picture of the atom is its *emptiness*.

Professor Andrade compares an atom to a plum round which a swarm of gnats are flying in fixed curves. In his picture the plum takes the place of the central "sun," and the gnats the place of the specks of electricity. Then he goes on to say that, if an atom were made bigger and bigger until its "sun" became the size of a plum, the gnats would be flying about *one thousand feet* away from it.

Sir James Jeans tells the same story in another way. He asks us to think of a few wasps flying around inside Waterloo Station. That is what the specks of electricity are like flying around inside the space taken up by an atom.

I quite agree that this sort of thing takes a lot of swallowing. How on earth, you will ask, does a scattered affair like that hold together? You are ready to believe that the radium atom is apt to break up, but you feel that even the

lighter atoms must be just as apt to fly to pieces.

Very well. But how does the solar system hold together? The planets are just as widely scattered as the specks of electricity in the atom. You would have to travel 5600 million miles in getting from one side of the solar system to the other; yet inside that enormous space there are the sun, the planets with their moons, and the clouds of star fragments called "asteroids." The space taken up by the solar system is as "empty" as Waterloo Station with its few wasps. And that does not prevent the solar system holding together. As a matter of fact, the whole bag of tricks is flying through space about 800 times faster than an express train.

It is "gravity" which holds the solar system together. The pull which draws the apple to the ground holds the planets on their courses round the sun, and our moon in its monthly tour round the earth.

The same sort of pull holds the atom

c

together. You will remember that, in the bursting of the uranium and radium atoms, two kinds of particles were shot off, the one kind being *positive* electricity and the other *negative* electricity. Almost the first thing one learns about electricity is that "like electricities repel each other; unlike electricities attract each other." So, if you will imagine an atom with a heavy "sun" of positive electricity and a swarm of "planets" of negative electricity, you will see how the positive sun, by attracting the whirling planets, holds them in their courses.

It is a wonderful thought that exactly the same law of attraction applies to the tiny atom as to the gigantic solar system. We shall see later that the solar system is tiny compared with the starry systems, and also that among these super-giants the same law holds. When we get among the stars the distances are too big for words. When we get among the atoms, they are too small for words. Big or small makes no difference to this law, which the

great Isaac Newton discovered and called the "law of gravitation."

At first sight it is rather puzzling to see how a pull can keep one body turning *round* another. Why, for example, does the earth not simply pull the moon down as it pulls an apple that drops off the branch? The reason is that the moon is not, like a hanging apple, at rest. It has a movement of its own; and if the earth did not hold it, the moon would simply go straight on along its own course. Between its own motion, which would carry it away, and the pull of the earth, the moon is forced to circle round us. Just in the same way the earth travels in a slightly flattened circle round the sun.

The moon completes its circle once a month, the earth once a year. What about the specks of negative electricity that circle the atomic "sun" of positive electricity?

If I tell you that they cover several hundred miles every second, you may open your eyes. Our earth does only

18½ miles per second in its journey round the sun. The specks, then, are travelling ever so much faster. But what makes the speed of the specks so astonishing is the smallness of their journey. They circle round their "sun" several *thousand million million* times every second. Their circle is so tiny that you must divide an inch into one million parts, and each millionth part into one hundred to get near to the size of it. Yet the speck of electricity is spinning round in this weeny circle faster than any planet sweeps round the sun.

It is, of course, because it spins so fast that the speck manages to keep away from the central sun which is pulling it all the time. Keeping its speed in mind, you will be quite ready to understand how, when the atom bursts, the specks are found flying away nearly as fast as light, which covers 186,000 *miles* in one second.

Before I say more about the inside of the atom I would like to introduce you to two or three words you may not have

met before. They are easy words, and very useful ones.

The right name for what I have been calling "specks of electricity" is *electrons*.

Electrons are specks of *negative* electricity. The heavier specks of *positive* electricity which are found in the "sun" of the atom, and are thrown off by the uranium atom, are called *protons*.

All the atoms are made up of protons and electrons. The lightest atom (that of hydrogen) is made up of one proton and one electron. Nothing could be simpler—the lightest sun with a single electron planet spinning round it.

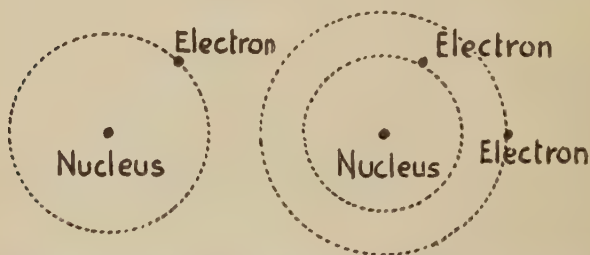
After hydrogen comes helium, a gas used in airships because it is next in lightness to hydrogen and does not catch fire. Helium has two electrons spinning round its sun.

You will notice that I do not call the helium sun a proton. It is not so simple as that. It is not even so simple as a bunch of protons. In every atom heavier than hydrogen the "sun" seems to be

58 WHAT IS INSIDE THE ATOM?

made up of protons *and* electrons all tightly packed together. This mixed bunch is called a *nucleus*, from the Latin word meaning "a small nut."

As I have already hinted to you, practically all the weight of an atom is in the



The circle on the left hand stands for the Hydrogen Atom, which has one electron spinning round the nucleus. The circles on the right stand for the Helium Atom, with two electrons. All the other atoms might be pictured in the same sort of way, with more electrons in their "orbits" like planets round the sun.

nucleus, just as practically all the weight of the solar system is in the sun. The electrons in the nucleus do not add anything worth talking about to the weight of the atom, but they do balance some of the positive electricity in the nucleus. The unbalanced part in the nucleus is balanced

by the electrons spinning round it, because the atom in its usual state is neither positive nor negative; it is neutral.

I hope you do not find this too puzzling, because if it is clear to you I can go on to explain how all the atoms, all the "elements" I spoke about before, can be described *in numbers*.

Take the case of helium, which is four times heavier than hydrogen with its simple proton and electron. Helium has two electrons spinning round its nucleus, which is made up of four protons and two electrons.

Take, again, the case of sodium, the metal which combines with the gas chlorine to form "common salt." The nucleus of sodium has twenty-three protons and twelve electrons. Round the nucleus are spinning eleven electrons. These numbers are not a mere matter of chance. Add together the numbers of electrons—eleven and twelve—and you get twenty-three, which is the exact number of protons in the nucleus. In this way the electricity of

the protons balances the electricity in the electrons.

And so we might go on right through the list of elements. When we get to the heaviest—uranium—we have ninety-two electrons spinning round a nucleus packed with 238 protons and 146 electrons !

With such a crowd of electrons and protons to keep in order, is it any wonder that the uranium atom gives it up as a bad job and bursts? The old woman who lived in a shoe and had so many children that she didn't know what to do had an easy task compared with the uranium atom. As Mr. Bertrand Russell says in his book on *The A.B.C. of Atoms* : "The overcrowding in the nucleus of a heavy atom must be something fearful." All these 238 protons and 146 electrons in the uranium nucleus are squeezed into a space measured by one millionth part of a millionth part of an inch. It is no wonder, as he adds, that the protons and electrons move fast when they escape from this slum !

The nucleus of the atom seems, indeed, to be the only really crowded spot in the world. Apart from the nucleus, most of the atom is, as I have already hinted, empty space. What little there is in it is *electricity*.

In the next chapter I shall take a look back over the long road we have travelled so quickly, but it may help you if I sum up what we have learned in this chapter :—

Every atom is like a solar system, with a heavy “sun” in the centre and light “planets” revolving round it.

Although so tiny, the atom is just as empty as the solar system. It holds together by the action of the same law of attractions.

Every atom is made up of “protons” (positive electricity) and “electrons” (negative electricity).

Protons and electrons packed together form the “sun” or nucleus of the atom. The electrons whirling round the nucleus balance the electricity in the nucleus.

The lightest atom—hydrogen—has one central proton and one electron revolving round it. The heaviest atom—uranium—has a nucleus of 238 protons and 146 electrons, with 92 electrons revolving round it.

All atoms are built up of electricity, and the differences between them are due to the differences in the number of protons and electrons inside them.

CHAPTER V

EVERYTHING MADE OF ELECTRICITY

NOW, I think, we can pause and look back over the road we have travelled since we asked ourselves the question, "What are we made of?"

Our first answer was that we are made out of the same stuff as the world around us. We next found that this stuff was made up of elements, of which ninety had been discovered. These elements showed here and there a "family likeness" which suggested that they were in some way related to each other. Then we discovered, through the bursting of the heavy atoms of uranium and radium, that matter was just electricity, and that the different atoms were kinds of "solar systems," with positive electricity as the "sun" and

negative electricity spinning round like the planets.

Step by step we have gone ahead, until we reached this answer to our question :—
We are made of electricity.

“ Perhaps so,” I can hear you say, “ but what is electricity ? ”

There is an old story of a student who was asked this very question in an oral examination. He looked very wise and very worried, and finally said : “ I did know, but I’ve forgotten.” “ What a pity ! ” exclaimed the examiner. “ Here is the one man in the world who knew what electricity is, and he has forgotten ! ”

We need not, however, feel sad because this question is so difficult to answer. When we ask ourselves what anything is, we try to show how the thing is related to something simpler. Just as I explained the word *nucleus* by saying that it meant a little nut, so I have “ explained ” all the different elements by saying that they were built up out of electricity. That is as far as we are able to get at present. Some day we may

discover that positive electricity and negative electricity are two forms of one thing, but so far they are the deepest roots that we have dug up.

Electricity *is*, I admit, mysterious. The whole world is mysterious. But every day we are finding out more about it, by learning how it works.

Now, it is a curious thing that we can tell, in a wonderfully exact way, how electricity works. We can measure it to the last electron, as you might say. Looked at in this way, we know more about electricity than our grandfathers knew about water or wood, or a host of things they did not think of as in any way mysterious.

All that, however, is a little off our track. What I really want to drive home in this chapter is the point—which I mentioned before—that there is no such thing in the world as “dead” matter. Nothing is ever really at rest.

In the “Brownian Movement,” which I spoke of in Chapter II, the atoms in a liquid

jostle each other. Here we have true "perpetual motion." All sorts of inventors have tried to make machines which would go on working for ever and ever. Nature has given us one in the "Brownian Movement," and also in gases, since there the particles are dashing about all the time.

But this kind of "life," fussy as it is, is nothing to what goes on inside the atom. The atom is a perpetual merry-go-round. Each second, night and day, year in and year out, century after century, the electrons in every atom—except, of course, those heavy ones which are breaking up—whirl round the nucleus millions and millions of times.

There are millions of these ever-busy electrons and protons in every grain of sand, in every tiny cloud-drop. There are millions of them in every hair of our heads, every grain of our flesh, every drop of our blood. Our bodies are made up of countless atoms of different sorts, linked together and working together in all sorts of ways, and all humming with perpetual motion.

There is no reason, therefore, to picture atoms as billiard-balls which need to be pushed before they move. They are not "born tired." They are full of energy, down to the last electron. However lazy we may be over our lessons or about getting up in the morning, the stuff we are made of is always at work and never sleeps.

I might, indeed, pack the whole story into three short sentences:—

(1) *We—and everything else in the world—are made of electricity.*

(2) *Electricity is energy.*

(3) *Every atom is a storehouse of energy.*

There is a story attached to No. 3—a romantic story which is only just beginning. It has to do with breaking into the storehouse and capturing its energy to do our work for us instead of coal and petrol and waterfalls and the other things we use to-day.

In uranium and radium the storehouse is breaking up of its own accord. The breaking up takes a long, long time, and we have

not yet found any way of hurrying it up. For example, a pound of uranium would, when every atom in it had broken up, yield enough energy to drive a liner across the Atlantic. Unfortunately, it would take one thousand million years to do the trick !

This energy, by the way, comes from the breaking-up of the *nucleus*, not simply from the escape of the electrons. It is the nucleus that is the real storehouse, and if we could find a way of smashing it up and setting its energy free we could get, out of a few pounds of earth, enough power to drive all our factories and railway trains and motor-cars for years.

When I was a boy I used to devour the stories of Jules Verne. Perhaps you have never even heard of Jules Verne. Certainly it is very unlikely that you have ever read any of his stories, for they are quite out of date now. They told of wonderful adventures with airships and submarines and other inventions which are so familiar to-day that you think very little about them. In Jules Verne's day, however, they were

dreams, and many people thought they were impossible dreams.

So it may be with the storehouse of power in the atom. Although it seems impossible to us at present that we shall ever unlock the secret doors, we may yet find a way.

Our hopes of success are brightened by the wonderful experiments of Sir Ernest Rutherford in the Cavendish Laboratory at Cambridge.

You will remember the positive particles which shoot out from the bursting atoms of radium or uranium. Sir Ernest tried what could be done by bombarding atoms with these shots, and he found that now and again a particle would hit the nucleus of an atom and knock a chip off it. He also found that the chip came away with more energy in it than the particle that knocked it off.

In other words, the flying particle did an occasional "smash-and-grab" raid on the storehouse in the nucleus, and "got away with it."

Of course, the "swag" is so frightfully

small that it is hardly worth talking about. As the nucleus of each atom is so tiny, and as most of the atom is empty space, the chances of a direct hit are few and far between. Professor Andrade says it is as if men, when out shooting pheasants blindfolded, let off their guns at random in the direction from which the birds were coming. For every million particles fired at the atoms, only one or two hits are made.

All the same, the trick has been done. We *can* do something to start, in ordinary atoms, the break-up that goes on "on its own" in radium and uranium. Some day—fifty, a hundred, two hundred years hence—we may be simply "tapping the atom" for all the power we want.

However that may be, the storehouse is there. We ourselves, and everything we see and touch and know of in this world of ours, are thrilling with motion and full of energy.

We have made this discovery by beginning with ourselves and going step by step from

smaller things down to the smallest particles and the smallest parts of the smallest particles. This is only one half of the world we live in. Let us now turn to the other half, and see what it has to tell us—the half that lies beyond the moon, beyond the sun, millions and millions of miles away among the stars.

CHAPTER VI

THE SUN AND PLANET FAMILY

WHILE I was working at the last Chapter a certain young lady of fifteen asked me what I was busy over. I told her I was writing a book about what she was made of, and I hoped that one day she would read it.

“Ho!” she exclaimed, with her nose in the air, “I don’t care a bit what I am made of. All I am interested in is Latin and Greek.”

This, you will admit, was not very encouraging. At the age of fifteen I had thought Latin and Greek the dullest things on earth, yet here was a grown-up child who thought the subject of my book ever so much duller than Latin or Greek!

However, I took heart. If she thrilled at the idea of translating dead languages,

I might be able to stir her with the living romance of science.

“Wouldn’t it interest you,” I asked, “if I told you how we discovered in the sun something we did not find on the earth till twenty-eight years afterwards? Would it bore you to hear that we can weigh the stars and can tell, just by looking into a little instrument, whether they are flying towards us or rushing away from us? Doesn’t it tickle you to hear that there are stars so far away that the light reaching us to-day started when King John was making a frightful fuss about Magna Carta, or even when the men of the Stone Age were just beginning to get clever with the splitting and polishing of flint arrow-heads and axes?”

Here, I think, I got home. I had a whole pocketful of other marvels ready to hurl at her, but they were not needed. I had set her wondering, and I began to have hopes that, even if she did skip a page or two about the atoms and electrons buzzing by the million million inside her, she might

look upon a journey over the Milky Way to the back of beyond as a holiday trip.

There is only one star-story that appeals to me more than the one about the finding of a new element in the sun—ninety-two million miles away—before it was known on earth. I shall tell the other story in a little while. The first one, about the element called helium, begins with a rainbow.

A rainbow is caused by the tiny drops of water in a cloud splitting up the light of the sun. (Mixed together, the colours of the rainbow make white.) You can get the same effect by looking through a three-cornered piece of glass, known as a prism. By putting the prism in a box with a narrow slit cut in it, so that only a thin beam of light enters, you can make the band of rainbow colours much more distinct. An instrument of this kind is called a spectroscope, and the band of colours a *spectrum*.

A spectrum, then, is a kind of light signal. Every shining thing sends out its

own special signal. An electric lamp sends a different signal from the sun's, or a candle's, or a coal fire's. Every element, indeed, sends its own signal, which the wise men in our laboratories can read as easily as Nelson's captains read his famous signal flags on Trafalgar Day.

In 1868 there was a total eclipse of the sun. During that eclipse the light from the flaming fringe of the sun was examined in the spectroscope, and the spectrum included a signal which had never been noticed before. Nothing known on earth gave the same signal. The new element, whatever it was, seemed to exist only in the sun's envelope, so it was called *helium*, after the Greek word *helios*, meaning the sun.

In 1895, however, Sir William Ramsay, examining a mineral called uranianite, noticed exactly the same signal in the spectroscope. Helium had been with us all the time. Since then it has been found in many other minerals, and we have learned how to make quantities of it to fill our airships.

What is still more remarkable, helium has been detected in certain stars.

I tell this story not just because it is a scientific "thriller," but mainly because it reminds us that the stuff we are made of, and that our earth is made of, is the same stuff as we find in the sun and in the stars.

No fewer than sixty-six of the elements known on our earth have been found in the sun. As most of our ninety elements are rare, we need not be surprised that all of them have not yet been detected in a flaming globe ninety-two million miles away. Sixty-six out of ninety is a good enough proportion to make us sure that the earth and the sun are so closely related that the earth might have been born from the sun itself.

This idea came into men's minds a long time ago. When they looked at the central sun, with the planets—Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune—revolving round it, they

naturally felt that these bodies belonged to one family, as it were. The more they examined the solar system, the stronger this feeling grew. Our moon looks just as if it were a little blob flung off from the earth when the earth was in a molten condition. Mars, again, has two tiny "moons," one only ten miles across. Jupiter, the biggest of the planets, has nine moons. Saturn, the next largest, also has nine moons; and it has, in addition, a beautiful system of "rings" which are made up of swarms of tiny moons. Uranus has four moons; and Neptune, which is furthest away from the sun, has one.

In between Mars and Jupiter, where there is a tremendous gap, there are about two thousand "minor planets" or "asteroids," all revolving round the sun like their big brother planets, although they are so small that they are detected only by faint trails of light across the photographic "star maps" taken by powerful telescopes.

These are the main members of the Sun Family. The others are the comets and the

meteors, both of which have some interesting things to tell us.

Comets are filmy clouds, sometimes with heads hundreds of thousands of miles across and tails twice as long as from the earth to the sun. They come from parts beyond the furthest planet, circle close to the sun, and go off again on their long journey outside the family circle. The spectroscope shows them to contain hydrogen, oxygen, sodium, and iron—all familiar elements.

Meteors are fragments which become visible when they are drawn down to earth and get hot as they rush through the air. Generally these "shooting stars" are burned up before they reach the ground, but quite a number survive the journey and find a home in our museums. When they are analysed by chemists, they are found to be made of iron and other well-known elements, thus giving us further proof that the stuff "in the sky" is the same as on our earth.

You may have read in the newspapers now and again that a shower of shooting-stars

may be expected on certain nights. How can astronomers know that on such and such a night we shall have this sort of display? It is because the meteors move in a vast swarm in a flat oval track round the sun. This swarm has its regular path just like a planet, or rather a comet, because a planet's course is nearer to a circle. When the earth's course cuts the track of the swarm we may expect a fine show of celestial fireworks. During one of these shows the meteors flashed at the rate of 75,000 an hour.

You will find plenty more facts about the Sun Family in books on astronomy. I have picked out a few important ones just to let you see that all the members of the family—big planets, the planets' moons, the minor planets, the comets, and the meteors—all obey the family law and revolve in known paths, either round the grandmother sun or (in the case of the moons) round the-mother planets.

The family law in the gigantic merry-go-

round of the solar system is, as I mentioned in an earlier Chapter, the same as in the tiny merry-go-round of the atom. It was discovered by watching and measuring the paths of the big planets round the sun; and we have to thank the genius of Newton for finding out that the "law of gravitation" applied to the planets as well as to the falling of an apple to the earth.

Less than one hundred years ago—and more than one hundred years after Newton declared the law—his law was the means of discovering the planet Neptune. Astronomers had noticed that the planet Uranus did not exactly follow the path it should take. Every planet moves under the pull of the sun and of the other planets near enough and large enough to influence it; but Uranus seemed to be wobbling off the track it might be expected to follow under the pull of the planets so far known to exist.

In 1843 a young mathematician called Adam set to work calculating, from the wobbles, where and what the disturbing pull might be. When he had finished his

calculations he invited the astronomers to search a particular part of the sky for a new planet.

About the same time a French astronomer, Le Verrier, had been working on the same problem, and had "found" the unknown planet in almost exactly the same part of the sky. With some difficulty the astronomers fixed it. A point of light which had been mapped as a fixed star was now discovered to be a planet, further away from the sun than all the others, and completing its circuit in one hundred and sixty-five years.

It is a wonderful thing, when you come to think of it, that a man is able, by working out a lot of sums on paper, to say to the astronomers: "Turn your telescopes to such and such a point of the sky, and you will see a bright point which is not a star but a planet which weighs so much, is distant so many million miles from the sun, and completes its journey round the sun in so many years."

The romance of the discovery of Nep-

tune has been followed by another "thriller"—the discovery of Pluto. Neptune was supposed to be the furthest planet, but the more the tracks of Neptune and Uranus were studied the more it was suspected that both of them were being pulled about—not much, but still enough to call for notice—by still another planet. The search for the stranger was taken up by watchers with the most powerful telescopes. These watchers, by the way, do not trust to their eyes alone. They take photographs of the stars on very, very sensitive plates, and the telescopes are moved by clockwork, so that they keep for hours on the same part of the sky, thus giving the faintest stars a chance of getting their portraits taken in points of light.

If a telescope taking photographs for a "star-map" happens to be pointing to a place where there is a planet, you get the same sort of effect as when a photographer takes a family group and somebody in it moves. The moving figure shows up in a kind of streaky fashion, while all the others come out clear and sharp. So in a

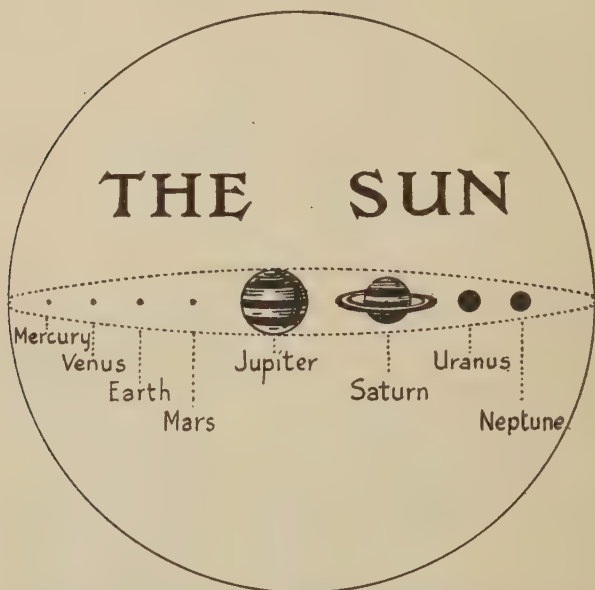
star map the fixed stars are points of light, and the planet makes a streak of light across the photograph.

The 2000 odd "minor" planets have, as I hinted above, been found in this way. "Pluto," the latest real planet to be discovered, is about half as big across as the earth, and does its round of the sun in something like 250 years.

The list of planets on page 76 gives them in their order from the sun—leaving out Pluto, about which a good deal has yet to be learned. If we were to make a Cook's Tour of the planets in this order we would feel as if we were travelling at first from one island to another, then to a huge continent or two, and back to small islands. The middle planets are the biggest. Jupiter is far and away the biggest brother in the family, and Saturn is the next biggest. Leaving out Jupiter, Saturn is five times bigger than all the other planets rolled together.

At first sight this does not seem to mean

very much. It looks a mere matter of chance that the sun's big children are in the middle of the little ones. But we shall



The big circle stands for the Sun; and inside it are dots and circles standing for the planets in their order from the Sun, beginning with Mercury. This diagram shows how immensely bigger the Sun is than the planets, and how big Jupiter and Saturn are compared with the other planets.

see later that it means a great deal. It helps us to answer the questions, "How did this sun and planet family come into being?"

Was the solar system always like what it is now, or did it grow out of something quite different? ”

We shall not be able to answer these questions until we have continued our Cook's Tour among the stars themselves. As the nearest star is so far away that its light takes four and a quarter *years* to travel the distance—and light you know, covers 186,000 miles in *one second*—you may think I am pulling your leg when I speak of learning anything at all about our earth and the other planets from things so terrifically far away. What can we possibly learn from stars twenty-five million million miles away?

All the same, you will find that I am right. We know quite a lot about the stars—how big they are, how heavy they are, how hot or how cold they are—and “in the light of the stars” we discover more of the secrets of the sun and planet family to which our earth belongs.

Before we leave the sun and planet family, we can get a good idea of how it is arranged

from the model described by Professor Smart, of the University Observatory, Cambridge. It would not be very easy, I admit, to build this model, as you would need a field more than a mile wide in every direction. But you can easily make a picture of it in your mind.

In the centre of the field is a globe, two feet across. This stands for the Sun. Then you would arrange various objects, from a pin's-head to a plum, at different distances from the globe. Each of these objects stands for a planet, in this fashion :—

Planet.	Object.	Distance from Globe (Sun).
Mercury	Pin's head	28 yards
Venus	Pea	52 „
Earth	Pea	72 „
Mars	Large pin's head	110 „
Minor Planets	Grains of sand and specks of dust	120–390 yards
Jupiter	Medium-sized orange	390 yards
Saturn	Small orange	690 „
Uranus	Small plum	Four-fifths of a mile
Neptune	Large plum	A mile and 9 fifths.

When you think of this model you will be amazed at the way the sun and planet family is scattered. The field with the sun and planets is just as "empty" as the atom with its central nucleus and its electrons. But just as the atom holds together, so the sun and planet family holds together. It is careering through space like an atom of hydrogen flying about in a balloon. And, like the atom in a gas, it has plenty of room to move. Suppose you wanted to go on with the model and add a few stars in their proper places, where would you have to put the nearest one so as to make the model stand for the stars as well as the sun and planet family? Why, 11,000 *miles* away from the two feet globe that stands for the sun!

CHAPTER VII

WHAT ARE THE STARS MADE OF?

WHEN I was young I used to delight in the lectures given by Sir Robert Ball on astronomy. He had a wonderful way of rolling off figures of millions of millions of miles. But no matter how cleverly he tried to describe the huge distances among the stars, I never could get a real picture of them into my head.

Neither, for that matter, could anybody else. When we are talking about atoms, things are so small that they are beyond us. When we are talking about stars, things are so big that once more they are beyond us.

Gulliver did not find it easy to get used to the midgets of Lilliput and then to the giants of Brobdingnag. What we have to do is ever so much more difficult. In

our tour of the stars we have to get used to distances so enormous that a million miles mean nothing at all.

Our ancestors had no idea that the stars were anything like so far away. They thought that the stars were simply lamps hung on the "firmament"—that blue dome fixed over the flat earth. Even when they came to understand that the earth was a globe revolving round a sun millions of miles away, they did not suspect that the stars were so remote as they really are. Not till about a hundred years ago was the distance of any star measured.

The nearest star, as I mentioned in the last Chapter, is 25 million million miles away. Let me write this out in figures:—25,000,000,000,000 *miles*.

It is quite a business writing out long rows of noughts like that. And if we wrote down the distance of the *furthest* known star in the same way, we would pretty well fill a page with figures. To get rid of these clumsy processions of figures the astronomers use a yard-measure of

their own—the *distance travelled by light in a year*. Since light takes about $4\frac{1}{4}$ years to travel from the nearest star to us, they say that the nearest star is $4\frac{1}{4}$ *light-years* away.

Sir James Jeans has given us a way of getting such distances into our heads. Wireless waves travel as fast as light (186,000 miles in each second). So a B.B.C. concert broadcast to-night might be heard by the people in the nearest star (if there are any people there!) $4\frac{1}{4}$ years hence. There are other stars so far away that their inhabitants would not yet have heard a wireless concert even if it had been broadcast before the Pyramids were built, or even before man himself had appeared on the earth! Their distance is measured not in a few light-years, but in thousands of light-years.

I do not mention these things merely to make you gasp and cry “help!” What I am after is to give you some idea of the enormous spaces among the stars and—still more—some idea of how this gigantic star-world is built up. We have had a

look into the machinery of the atom. We have had a glimpse of the way the solar system works. We shall now set out to see whether there is any order, any system, among the stars.

I used to think that we could never make head or tail of the tangle of the stars. There were far too many of them, and they were far too far away, for us to be able to sort them out. Our telescopes, instead of making the thing easier, seemed to muddle us more by revealing still more stars. Each of us, for example, can see about 3000 stars with our own eyes. When Galileo made his first telescope he brought about a hundred times as many stars into sight. To-day, with our big telescopes which photograph stars so faint that the eye cannot see them, we have learned of the existence of over fifteen hundred million stars in the "Milky Way" alone. There are, as we shall see, millions of star systems, each with about as many stars as the Milky Way.

What can we make of a crowd like that? When we look at a star-map we see a bewildering crowded maze of points of light, among which, we imagine, we must simply get lost. The job is surely too colossal for tiny little men on a tiny little planet in a hardly less tiny solar system lost in the immensities of space.

All the same, you yourself know enough already to be able to say that there *must* be order among the millions of stars. You know that they are made of the same stuff as the earth and the sun. The light signals sent through the spectroscope by the stars are those of familiar elements. In some cases, it is true, they are "like nothing on earth," but that is because certain stars are terrifically hot. The elements are the same old friends; they behave differently in the stars because there they are at temperatures far higher even than the hottest regions in the flaming sun.

The stars, then, are, like the sun and our earth and ourselves, made of electricity, of atoms with their protons and electrons.

We may therefore expect them to follow the laws we have discovered on earth and in the sun and planet family. However far away they may be from us, they still "belong" to us. Our sun is simply a star. The whole universe is one great family.

It would not be easy to believe this if the stars were really "fixed stars." Nothing in our world, we found, was really at rest. With every atom "on the go," it would be strange indeed if the millions and millions of stars were absolutely still.

When the old astronomers divided the stars into "fixed stars" and "wandering stars" (or planets) they thought that the fixed stars were really fixed. We need not blame them for their ignorance, because they saw no sign whatever of movement among the stars. Indeed, the heavens to-day would seem much the same to any ancient Babylonian astronomer who might be brought to life again.

Yet the stars are never at rest. They are always moving, like the sun and the earth and every atom of matter every-

where. The reason why they seem at rest is that they are so far away. An aeroplane flying high seems to move much more slowly than a bird a few feet away; in the same way a star 25,000,000,000,000 miles away may be rushing through space without appearing, in our view, to move at all.

By mapping the stars carefully year after



"Fixed" stars are not really fixed. The left-hand picture gives the shape of the "Plough" as it is to-day. The right-hand one shows the "Plough" as it will be thousands of years hence.

year for a century or more, astronomers have been able to detect changes in the position of many stars. The "Plough," for example, which is so well known because the two end stars point to the Pole Star, has changed its form. It has been watched so closely that we can tell what it will be like thousands of years hence.

We have, however, a still better way of proving that stars move. All we need to do is to look at them through the spectro-

scope. You will remember that the light-signal given in the spectroscope is a series of lines, each with its own position and its own meaning. It was found that, if the body sending out the light-signal were moving towards the spectroscope, the lines would shift in one direction; and if the body were moving away from the spectroscope, they would shift in the other direction. So we can tell, by looking at a star through a spectroscope, whether the star is rushing towards us or away from us.

More than that, we can tell how fast it is coming or going. After we have measured how far the lines have shifted to left or right, quite a simple "sum" gives us the speed of the star towards us or away from us, as the case may be.

Among all our marvellous inventions, I know nothing more marvellous than this simple and sure process of measuring the speed of a star countless millions of miles away.

Even without our wonderful spectroscope,

and without the mapping of the stars over a century or two, we could still prove that the "fixed" stars are really moving.

There are some stars, called "runaways" or "flying" stars, which move so much more quickly than most of their companions that their change of position can be discovered quite easily. Much more interesting and useful, however, are the Heavenly Twins known as "double stars."

The discovery of "double stars" was made almost by accident. It reminds us of one of Lear's "Nonsense Verses":—

I thought I saw a butterfly
 Upon the mantelpiece;
 I looked again and saw it was
 My sister's husband's niece.

The great astronomer, Sir William Herschel, was looking for signs that the stars changed their position in the sky. He did find changes of position, but not of the kind he expected. Much to everybody's surprise, the changes he noticed were shown to be due to two stars waltzing round each other. In some cases it is a very

slow waltz, the couple taking hundreds of years to complete a single spin. But there is no doubt whatever that these circling twins exist. There are any number of them among the stars.

Now, these double stars tell us more than the simple fact that stars move. They tell us that Newton's law of gravitation, which controls the fall of the apple and the course of the earth and other planets round the sun, applies in exactly the same way to the stars. We might expect that it would, as the stars are made of the same stuff as our earth and the other members of the sun and planet family. But there, in the double stars, we have proof that the law works everywhere.

Sometimes a double star is so placed that one star as it swings round eclipses the other, by coming between us and it. We see the light fade slowly and then grow stronger again. By careful measurements in such cases our astronomers can tell the sizes and weights of the two stars and the

tracks they follow as they revolve round each other.

Over a thousand of these double stars already discovered are so far away and so close together that they show only a single point of light in the most powerful telescope. We know they are twins only because, when we look at them through the spectro-scope, we see a double light-signal, each part of which shifts in the way I have already described, proving that the source of light is moving towards us or away from us. While one part of the light-signal says "Advance," the other says "Retire," thus letting us know that one star is circling towards us while the other is circling away from us. In some double stars of this kind the circle is completed in two days.

Wonderful as these double stars may be, there are still more exciting things to be seen in a telescope.

For example, the "variable" stars. Most stars shine with a steady light, but in

some the light rises and falls, reminding us of a revolving lighthouse. When the star is a double one the change is, as we have seen, caused by one star hiding its twin. There are, however, variable stars which are not double ones. They glow and fade by turns, just, as Sir James Jeans says, "as though someone were throwing armfuls of fuel on to a bonfire at perfectly regular intervals."

We do not yet know why these stars behave in this peculiar way, or why some of them keep this regular time in their rising and falling, while others wobble up and down in an almost crazy fashion. Some day, perhaps, we shall solve the mystery. Ignorant as we are, however, we have to thank the regular variables for telling us quite a lot already about the heavens.

I should puzzle you too much if I went over all the ins and outs of these wonderful "variables." I need only tell you that the most brilliant variables are turned up and down more quickly than the duller ones.

Why it should be so we don't know; but it is so. By timing the ups and downs of any one of them we can tell how bright it really is. Then, if it does not seem bright to us, we know that it is very far away. The difference between the real brightness and the seeming brightness gives us a measure of the distance of the star.

These regular variables, which the astronomers call "Cepheid variables," are scattered all over the heavens. Wherever they may be, they help us find out how far away that region is. They are a kind of sounding-line into the depths of the sky. They tell us that some stars are millions of *light-years* away!

There are other ways of sounding the depths of space, but I need not worry you with them. You know that we can measure distances among the stars as well as among the planets of the solar system. Knowing this, you will be ready for the next Chapter, where I am going to try to give you a picture of what I may call, in big words,

“The Architecture of the Heavens.” The stars, we shall find, are not flung about all anyhow in space. They are *arranged*. We can think of them not as a heap of bricks, but as a house of bricks, built to a plan.

Somewhere in this house of the heavens we shall find a clue to the secret of the sun and planet family. That will be the end of our quest. But before I finish this Chapter I must rub in once more the wonderful fact that wherever we look we see the same law at work. From the electron circling round the proton to the gigantic double star thousands of light-years away from us, the same stuff is at work in the same way. The hydrogen atom, so small that we cannot imagine its size, is a model for the double star, so gigantic and so distant that our brain reels to think of it.

In the next Chapter we shall find that the same law holds for starry systems so huge that the biggest double-star is only a tiny fragment lost in their immensity, like a grain of dust in the Crystal Palace.

CHAPTER VIII

MYSTERIES OF THE MILKY WAY

I WELL remember the thrill I got when I first came across a hint that the heavens were arranged on a plan—not a very clear one, perhaps, but still a plan. I had read a good deal about how our globe, with its mountains and seas, had been built up; also how the sun and planets and the planet's moons had come to be as they were. But I had not thought much about the stars except as millions and millions of suns floating about at random in space so far away from us that we could not know very much what was happening there. And even if we did, I thought, it would not matter very much.

Then suddenly, in some book or other, I found what I might call a *pattern* for the heavens. It was just as if the jumbled-up

pieces of a jig-saw puzzle had, at the wave of a magician's wand, put themselves in their right order and made a picture.

As soon as this happened, I wondered why I had been so stupid as not to think of it long before. That often happens. We puzzle over something for a long time, and when somebody answers the riddle we say, "Of course! How simple!"

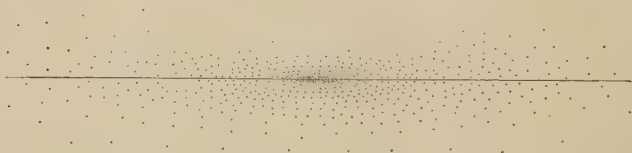
The key to the riddle of the heavens is "given away" on any clear night. Look up into the sky and you will see a filmy band of light which is well described by its old name of the "Milky Way." It stretches right over the sky from one side to another; and if you run right round the earth you could still find the Milky Way arching over you.

This means that the Milky Way makes a circle right round the earth—or, rather, right round the sun and planet family.

What is the Milky Way? Before telescopes were invented it was thought to be a shining cloud. Galileo's little telescope showed that the cloud was really a mass

of stars. They are so close together, and most of them are so faint, that, to our unaided eye, they merge into a haze of light. Even in a very powerful telescope the Milky Way is still "milky." (See p. III.)

So we see that we are somewhere inside a gigantic ring made up of crowds upon



Here is an attempt to give an idea of the shape of the "Milky Way" or "Galaxy." The dots representing stars are more crowded towards the centre of the Galaxy. Somewhere in this crowded centre is our Sun and Planet Family.

crowds of stars. Astronomers call this ring the "galactic system," but unless you are fond of big words you will be glad if I go on calling it the Milky Way. The easy name will do, although there is really much more in the "galactic system" than in the Milky Way as we see it in the sky.

The Milky Way is not just a ring, like a quoit. It is shaped more like a watch. Imagine yourself somewhere near the centre

of a mass of stars arranged in the flat-sided round form of a watch, and you will see that, if you look towards the face or the back of the watch, there are fewer stars than if you look sideways. You will, in fact, appear to be ringed with crowded stars in the Milky Way fashion, while above and below you the stars are more scattered.

The illustration on page 104 will help you, I think, to get the hang of the "galactic system." You must remember, however, that the earth is supposed to be somewhere near the flat blob in the centre of the crowd of dots indicating stars. Also, you must remember that the nearest star is 25,000,000,000,000 miles away from us!

Now I am going to stagger you with some figures about the numbers of stars in this Milky Way system, and about the size of it.

We do not, of course, know the exact number. Our biggest telescope has photographed about 1,500,000,000 (fifteen hundred million!). That is about one star for

each man, woman, and child in the whole world. Some of the stars are so faint as to be almost invisible, and we may be sure that a bigger telescope would show millions upon millions more. One astronomer has put the total at 30,000 millions, and another at 100,000 millions.

It is, I know, difficult to get any notion into one's head of what these numbers really mean. But Sir James Jeans suggests a way that helps. If we take the lower figure of 30,000 millions, it means that if every man, woman, and child in the world were to choose 20 stars each in the Milky Way, there would be just enough to go round!

As for the size of the Milky Way, this is much more difficult to grasp. Suppose I took you to the outside edge of the Milky Way and sent you flying across it with the speed of light, how long would you take in getting to the edge on the other side?

The answer is—*two hundred and twenty thousand years.*

We have not only measured the Milky

Way : we have weighed it. Of course, the figure our astronomers give is only an "estimate," which is another name for a good guess. But Professor Eddington, who is one of our greatest authorities, puts the weight of the "galactic system" at two hundred and seventy thousand million times that of our sun.

Once more, I am not giving you these colossal figures just to make you gasp. The really interesting thing about the Milky Way is that, although it contains such a multitude of stars, although it is so huge and so heavy, it has shape. The whole thing, colossal as it is, *holds together*. The sun and planet family, huge though it looks to us when we think of the 93,000,000 miles between us and the sun, is a mere speck swimming inside the circle of the "Milky Way"; and that circle, measuring 220,000 light-years across, is a real something on its own.

What has given it its shape? What holds it together? Why do all the millions of stars in the Milky Way not fly off into space, instead of crowding together to make that

beautiful band of light we see across the sky?

I expect you have already guessed the answer to these questions. I expect you have thought of how the atom holds together, how the apple is drawn to the earth, how the sun and planet family make a "solar system," and how the huge double stars join with all these in obeying the law of gravitation.

It was a great discovery when Newton found that the falling apple followed a law which governed the course of the planets round the sun. It was another great discovery when Herschel found the stars illustrating the same law. We have now gone a tremendous step further, and found the law at work in the system to which our sun belongs, as a humble, tiny member of a family of millions upon millions of stars.

One thing, perhaps, may still be puzzling you about this wonderful Milky Way.

If it holds together by the pull of gravitation, why does it take that peculiar flattened shape? Why does it not form

a round mass like the earth, or the sun, or one of the clusters of stars which we actually find inside the Milky Way circle?

I can lead you towards the answer by asking you another question: "Why is the earth shaped like an orange?" You will probably have learned at school that the earth is flatter at the poles because it was spinning when it was in a soft condition and bulged out round the equator by "centrifugal action." In much the same way the Milky Way is flat because the whole thing is turning round and round.

Astronomers guessed that it must be rotating, because of its shape. Then, by carefully watching the motion of the stars, they proved that it actually is going round and round. It is not exactly what we would call spinning, because it takes about 300 million years to do one complete turn. But when we remember the size of this Catherine Wheel, we may agree that one revolution in 300 million years is not bad going!

We are all the more sure about the behaviour of the Milky Way from what we

find when we go plunging into the depths of space in other parts of the sky. But before we take this plunge—which, by the way, will bring us back to earth in an unexpected way—I want to upset all your notions about the *crowds* of stars in the Milky Way.

A “crowd” of people is a large number so close together that they jostle each other. A crowded garden is one where the plants and trees get in each other’s way.

Look once more at the photograph of the Milky Way (page 111), and you will be ready to declare that the stars are packed as close as people at a football match. There really seems to be no room between them. On the other hand, *can* they be packed as near together as they appear to be? Remember, all these stars are on the move all the time. They are rushing around at a speed about one thousand times that of an express train. If they are crowded they are sure to smash into each other and give us a display of fireworks which would make a shower of meteors look silly. As we do not have these fireworks in the sky



Part of the " Milky Way " as seen through a telescope.

every night or any night at all, we begin to suspect that the stars must be very much further away from each other than they look.

When I was telling you about the inside of the atom, I quoted Sir James Jeans's description of the *emptiness* of the atom. He spoke of a few wasps flying about inside Waterloo Station. That was startling enough, but his picture of stars in space is still more startling. "Empty Waterloo Station," he says, "of everything except six specks of dust, and it is still more crowded with dust than space is with stars."

He has another way of helping us to realize just how empty is space. Take any star you like in the most "crowded" part of the Milky Way, and the chances are that it would career along for something like a million million million years before it collided with any other star. "The universe," says Sir James, "consists in the main not of stars but of desolate emptiness—inconceivably vast stretches of desert space in which the presence of a star is a rare and exceptional event."

There is no need, then, for celestial policemen to control the star traffic !

The crowded look of the Milky Way is, we now begin to understand, due to the enormous numbers of stars stretching away behind each other for more millions of miles than we can imagine. I can think of no better way of getting an idea of the vastness of space than to gaze at the Milky Way and remember that every star we see is a lonely wanderer, with no companion within millions and millions of miles.

It is perhaps as well for us—for the sun and planet family, I mean—that the chances of a collision are so slight. If a big star were to come anywhere near, it would break up the happy family. We seem to be safe from this intrusion for any number of millions of years. Yet the astronomers believe that the approach of a star had a lot to do with the *making* of the sun and planet family. They believe that a star swooping past “did the trick” which led to the planets being formed.

If they are right, it was by a very odd

chance that the Earth and the other members of the solar system came into being. No one can be sure, of course, whether the astronomers are right or wrong about the disturbing star. The best we and they can do is to guess what happened from what we know of the stars. And in the next Chapter I am going to tell you what we have learned, from the part of the sky outside the Milky Way, about how the sun and planets may have been born.

CHAPTER IX

HOW STARS ARE BORN

I FEEL tempted to head this Chapter “The Extra-Galactic Nebulæ,” but I am afraid these peculiar words would frighten you as they frightened the young lady of fifteen I mentioned in Chapter VI.

“Haven’t you finished that book yet?” she asked.

“No,” I replied solemnly; “I have only got as far as the extra-galactic nebulæ.”

She looked really startled. “Extra” was a familiar word, but “galactic” sounded like a strange medicine; and as for “nebulæ,” her notions of what it meant were distinctly—nebulous, shall I say?

By way of teasing her further I made up a rhyme about the mystery:—

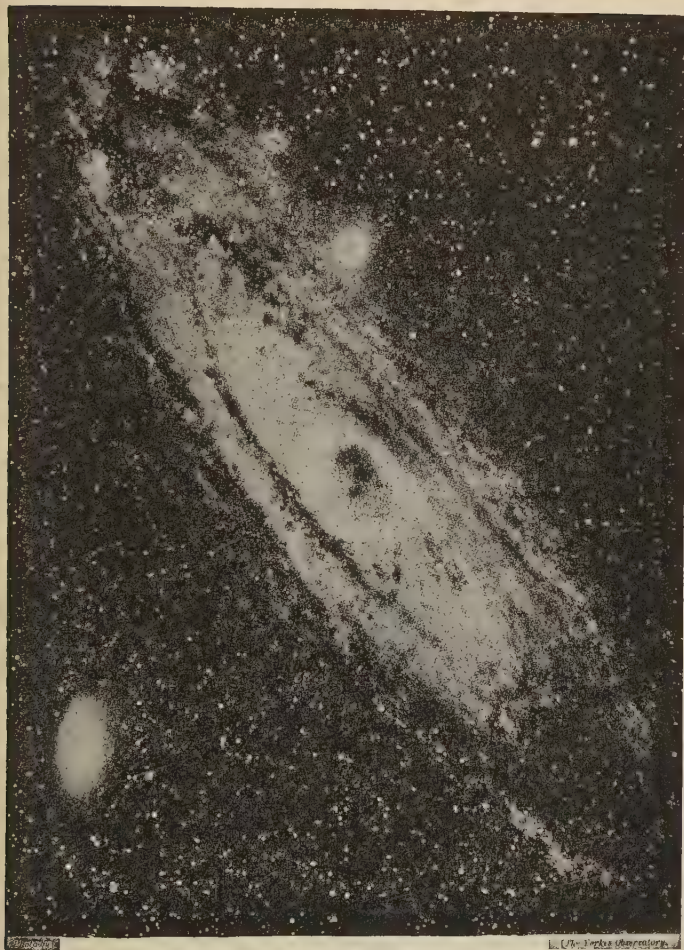
The extra-galactic nebulæ
Are right outside the Milky Way;
Millions there are, the wise men say,

Shaped like a lozenge, a wheel, or a tray,
All of them millions of miles away,
Dotting the heavens in bright array,
Never were clouds on earth so gay !

What are they made of, then, I pray ?
Legions of stars on holiday ?
Whether they merely whirl in play
Or some tremendous law obey,
These extra-galactic nebulae
Do not belong to the Milky Way.

This nonsense only puzzled her the more,
so I had to fall back on simply telling her in
plain words what I was talking about.

As she was so keen on Latin, she ought to
have known at once that "nebulae" are
clouds. When the first telescopes were
made they revealed, in the sky outside the
Milky Way region, a host of hazy clouds of
light. The largest of them—the Great
Nebula in the constellation labelled Andromeda
on a star-map—can just be seen
without a telescope. In 1612 an astronomer,
looking at it through a small telescope, said
it looked "like a candle-light seen through
horn." Through a big telescope it shows
itself to be a huge glowing wheel, made up of



The Great Nebula in Andromeda.

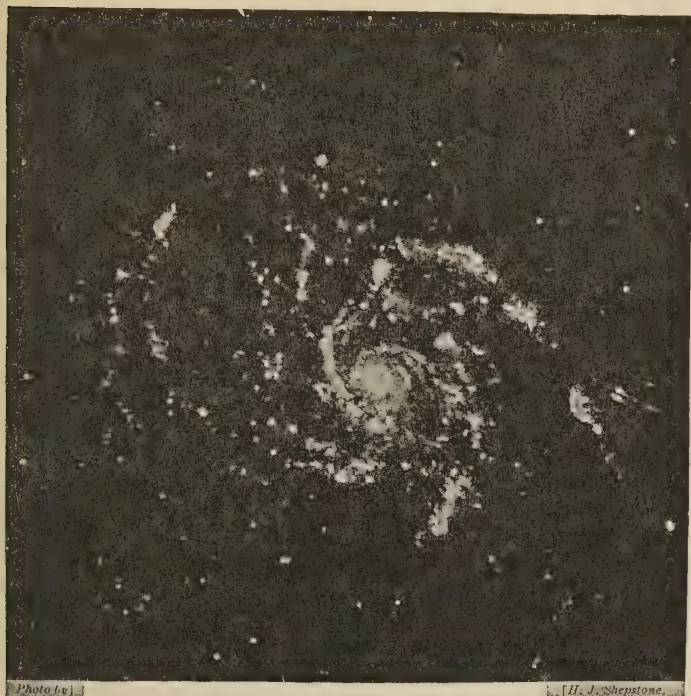
stars. (See page 117.) What was first taken to be a haze of light was then seen to be a mass of stars, each making its separate point of light.

You will remember that we went through the same stages over the Milky Way. To our naked eyes the Milky Way looks just a cloud of light. The first telescopes let us see that there were lots of stars among the cloud. As our telescopes were made bigger, and especially when we began to photograph the sky, we found that the Milky Way was really a multitude of stars.

Here you may begin to suspect that there is some link between the Milky Way—or the Galaxy, as the astronomers call it—and a nebula like that in Andromeda. Both are huge masses of stars. Both are round and flattish. Both are thicker in the centre and thinner towards the edges.

There is another likeness between them. If you will look carefully at the picture of the Great Nebula on page 117, you will see that it looks as if it were whirling round. On page 119 you will find another nebula

with this whirlpool look even more distinct, partly because we are looking square on to



A Nebula that looks like a Catherine Wheel.

the nebula, and not from an angle. This picture must, I think, remind you of a Catherine Wheel, that spins so beautifully when you fix it on a pin and light it.

These nebulae, then, are turning round and round, exactly as the Milky Way is turning. There is, indeed, no difference between the Milky Way and these nebulae, except that the Milky Way appears to be much bigger than any of the nebulae.

If our sun and planet family were tucked away in one of the spiral spokes of the Great Nebula in Andromeda, we should see that nebula as a "Milky Way," and what we now call the Milky Way or Galaxy would appear as a Great Nebula. So the "extra-galactic nebulae" are just the nebulae or clouds of stars which are outside ("extra") the Galaxy, or Milky Way, which is itself a huge nebula or cloud of stars.

What a different picture this gives of things from the quaint old one at the beginning of the book. That shows a flat earth with the sun and moon and stars on a dome overhead! The picture we have now in our minds is one of huge clouds of stars scattered about in a space so vast that we cannot really imagine how vast it is. The figures we have to

handle when we are talking about the nebulæ are bigger than anything I have mentioned yet, although some of these figures, you will admit, are staggering enough. To know that light would take 220,000 years to travel from one side of the Milky Way to the other is to feel that one has reached the limit; but 220,000 light-years are a mere nothing when we soar among the nebulæ.

Here are some facts about the nebulæ. Although you may not be able to take them in, you may be sure that I am not taking *you* in, because they are figures which our greatest astronomers have worked out :—

The Great Nebula in Andromeda is about 900,000 light-years away from us.

The nearest nebula is about 850,000 light-years away from us.

The furthest known nebula is about 140 *million* light-years away from us.

The average distance from one nebula to another is about 2,000,000 light-years.

There are about 2,000,000 of these nebulæ.

So much for distances and numbers. Now for weights. The weight of the Great Nebula in Andromeda is somewhere about 3500 million times that of our sun. Sir James Jeans says it seems likely that each of the nebulae contains enough to make 2000 million stars.

He does not mean that there are actually about 2000 million stars in each nebula. I have called the nebulae "clouds of stars," but the Great Nebula, like most of the others, has a centre part which looks like a smooth shining cloud even in the most powerful telescope. This centre part seems to be a mass of gas, a kind of gigantic puffed-out sun, which may in time break up into stars, but which has not yet done so.

Here we get a hint that the nebulae are not merely whirling in space, but are actually changing their shape as they do so. This hint is backed by the discovery that the nebulae are far from being all of the same shape, even in a general way, as the Great Nebula. They show quite a number of shapes, and the more we look at these and

compare them with each other, the more we feel that some are young nebulæ, some a little older, and so on to old age.

Before I say any more about that—and it is a very fascinating subject, which tells us a good deal about how our solar system may have grown up—I want to repeat some figures which will help you to remember that we have plenty of space and plenty of samples to play with when trying to find out about young, middle-aged, and old nebulæ :—

There are about 2,000,000 nebulæ.

Their average distance apart is about 2,000,000 light-years.

There is enough in each to make 2000 million stars.

A large number of these nebulæ are, like the Great Nebula, going round and round, steadily, like a spinning top. The Great Nebula would take about 19 million years to do a complete spin. This, you might say, is so slow that it means no speed at all; but the nebula is so amazingly large that its out-

side edge must move at a speed of *hundreds of miles per second* to get round in that time. As an express train goes at something like sixty miles *per hour*, it is clear that the rate at which the Great Nebula is revolving is much more than "no speed at all."

Now let us forget the nebulæ for a minute or two, and call on a Professor of Mathematics to answer two questions.

First—What would be the shape of a mass of gas floating in space without spinning?

Second—What would happen to the mass of gas if it started to spin?

The answer to the first question is that the gas would form a globe. Under the law of gravitation the gas would "pull itself together," and as the pull would be the same in every direction the result would be a ball of gas.

The answer to the second question is that the ball, when it began to spin, would bulge

out into the orange shape that our earth has, and Jupiter as well. As it went on spinning the gas would spread further and further out, passing through the shapes shown on page 127.

These two answers can be given simply by "doing sums." Having got the answers, let us call at an observatory and look through the big telescope at the nebulæ. What shall we find there? We shall find nebulæ with shapes exactly like those shown on page 127. Now we can say that the Professor of Mathematics has done his sums right, and that these nebulæ are spinning masses of gas !

Everything, of course, depends upon the nebulæ being made of the same stuff as the gases and other things we know on our earth. The spectroscope tells us that they are, just as it tells us that the nebulæ are spinning, and how fast they are spinning.

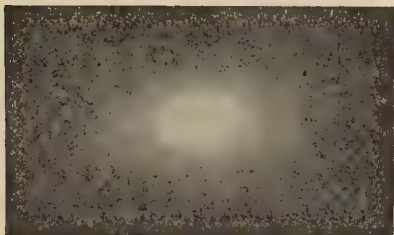
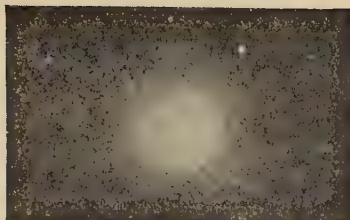
Our Professor of Mathematics, however, can go still further. He can prove to us that, in a huge cloud of gas like a young

nebula, parts of the cloud will tend to draw themselves together.

Imagine, if you like, a thousand boys in a huge playground. Supposing you place them at equal distances apart and leave them to do as they please. In a very short time they will have gathered into knots, talking and playing together. Your formless crowd (or cloud!) of boys will have broken up into a number of distinct groups.

Something of the same sort happens to the particles in a nebula. Here and there the particles gather into knots. The formless cloud of gas breaks up into a number of distinct groups. When we look at a nebula through the telescope we see each group as a point of light—otherwise *a star*.

The picture on page 119 shows a nebula which is well on into the “starrified” stage, if I may make a word to suit my purpose. This nebula has become little more than a bunch of stars. Nearly all the traces of the cloud out of which it was born have vanished. We can still see, however, the whirlpool shape of the nebula.



These photographs, taken at the Mount Wilson Observatory, America, are of different kinds of nebulæ. They suggest how a globe-like nebula gradually changes its shape until it forms a flat ring-shaped system with a central "sun."

Some of the bunches of stars—"star-clouds" they are called—are just huge bunches without any reminders of whirling nebulae. They seem to stand for the last stage in the old age of a nebula.

Some of you may have seen the wonderful "nature films" showing the growth of a seed into a full-sized plant. They are made by photographing the seed at every stage, and so getting a series of views which, when run through the projector, reveal on the screen the evolution or unfolding of the plant step by step from the seed.

Much in the same way we might, from the many photographs taken of nebulae in different stages, make up a film showing the unfolding or evolution of a system of stars from its "seed" in the form of a cloud of gas. We should, of course, need millions upon millions of years to follow any *one* nebula through its growth into stars. The best we can do is to pick and choose among the two million nebulae and make a patch-work which, we feel sure, tells much the same story as a single nebula would reveal

if we had the time to watch it from youth to old age.

If an insect which lives for a day saw only one man, it would be able to learn little about the growth of human beings, even if it had a brain like ours. But if it saw two million people of all ages, it might form a very shrewd notion of the growth of men and women from babies. That is very much what we do when we study these extraordinary extra-galactic nebulae.

We now feel fairly certain that the nebulae reveal the birth and growth of stars. The next question we have to ask them is:—Do they tell us anything about the birth and growth of *our* stars, the sun with its family of planets?

CHAPTER X

HOW WAS THE SUN AND PLANET FAMILY MADE?

IT is a rather curious thing that this question about the sun and planet family is in some ways the most difficult one we have to answer. It was the first question that astronomers tackled. Wise men have wondered about it for centuries, and here we are, after a tour of the heavens, asking ourselves the same old question.

There is no direct answer. We see in the heavens millions of stars of all kinds and all ages, and so, as we saw in the last Chapter, can tell from our own eyes something about the way stars are made. But nowhere in the sky do we discover anything like our solar system. There may be other sun-and-planet families, but if so they are too far away for us to see them, even in the biggest

telescope. We must guess, from what we know of the sun and planets, of things in general and nebulae in particular, how this interesting family came about.

The first guesses that were made imagined a gigantic cloud of gas spinning faster and faster until it threw off blobs of gas one after the other. Each blob of gas flung off made a planet, while the central cloud of gas shrank into the sun. Likewise, some of the planet-blobs in spinning flung off other blobs which became the moons of the planets.

This was all simple enough, and in a way likely enough. It did not, however, quite meet the case. It meant that in its young days our sun must have been a very giddy creature to spin fast enough to fling off the planets one by one. There is no sign at all that our staid old sun ever behaved like that. Everything we know about the sun goes to prove that it never spun at anything near the speed needed to make it break up into planets.

Again, the nebulae, although spinning,

are not spinning at the terrific rate of a cloud "on the burst." Once round in so many million years is not exactly giddy. If we found even one or two among the two million nebulae showing signs of breaking the speed record, we might say that *there* was a hint of how our sun may have behaved. But as they are all going quietly we must feel a little doubtful if anybody suggests that, for no clear reason, our sun took to doing something utterly different from any other star in the heavens.

Here we seem to come up against a blank wall. It is all very well to say that the sun could not have been spinning fast enough to throw off the planets. But the planets are there. They must have been "made" somehow. So what about it?

We can open a door through this blank wall by calling in the aid of a second star. Although we cannot see how a single star, floating in space right away from all other stars, could have made the planets, we can see how, if another star came swooping

near it, the visitor might have done what the star itself could never do.

Now you may remind me of what I told you in Chapter VIII of how unlikely it is that stars should ever come anywhere near each other. They are like a few specks of dust floating about inside Waterloo Station. Quite so, but there is all the difference in the world between the *unlikely* and the *impossible*. There is nothing impossible in two stars coming close to each other and even colliding. Considering the millions and millions of stars and the millions and millions of years they have been careering about in space, the odds are that somewhere and sometime there was a crash. It would certainly be a rare event, but not a surprising one. A little less rare would it be for two stars to fly so near each other as to give each other a tug, though they did not actually collide.

Supposing our sun had received a flying visit of this sort when it was an enormous mass of gas. What would have happened?

A clue to the answer is given by the tides in our seas. The tide "rises" in obedience to the pull of the moon and sun, the water "giving" to the pull and heaping itself up. Here, of course, we have the law of gravitation at work in a very striking way. As this law is at work everywhere, we know that a star drawing near another would tend to "raise tides," making a bulge on it just like the bulge of high tide water on our Earth.

As the visiting star came nearer to the other, the bulge would get bigger, because the pull became stronger. If the visitor were huge enough and came near enough, its pull would be powerful enough to draw stuff right out of the other star.

We have no need, therefore, to imagine our sun "bursting" by spinning faster than ever any star is known to have spun. Another giant flying near to it can do all the bursting we require.

Let us follow the bursting business a little further, and we shall come upon

something very interesting, at which I hinted on page 84.

The visiting star begins by drawing stuff out of our sun. The nearer it comes the more it will draw out, because its pull is getting stronger. So the arm of gas pulled out of the sun grows thicker and thicker until the visitor gets to its nearest point in its travel past the sun.

When this point is passed the pull gets less and less, and the thickness of the arm of gas gets less and less. In course of time the visitor is so far away that it is unable to draw any more gas from the sun, although it is still able to make mountainous tides on it. Still later, it departs so far into space that our sun is left in peace.

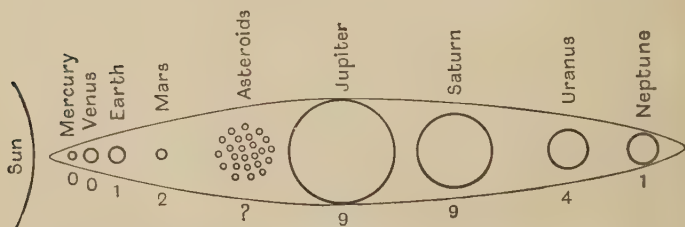
But not as it was originally. It has "grown" a gigantic arm stretching out for millions of miles. We can guess the shape of this arm from the way it has been formed by a pull which has got stronger and stronger until it reached its strongest and then got weaker and weaker until it died

away altogether. The shape would be something like this :—



Now we come to that very interesting something I mentioned a moment ago.

If we make a row of circles representing the planets in their sizes and in their order



When the planets are arranged in their order from the Sun, their sizes fit into a cigar-shaped figure. This helps us to understand how the planets might have been formed out of a cigar-shaped arm drawn by a passing star out of the Sun while it was a huge mass of flaming gas.

The figures 1, 2, 9, 9, 4, 1 are the numbers of the planets' moons.

from the sun, and if we draw a line right round the row of circles, we get a cigar shape exactly like the one above.

You have only got to look at these two

figures to see that a cigar-shaped arm drawn from the sun when it was a huge mass of gas would provide stuff to make a line of planets getting bigger up to the mid-way point and then getting smaller. The huge size of Jupiter and Saturn is not an accident. It is due to there being the greatest amount of stuff available in the middle of the arm.

Again, you will notice the curious way in which the number of moons gets bigger up to the middle of the arm and then gets smaller. The Earth and Neptune have only one moon, while Jupiter and Saturn have nine each. This, again, is in keeping with the notion that the planets were formed from a cigar-shaped arm drawn from the sun, with plenty of stuff in the middle for making big planets and lots of moons.

If you want to understand how the planets were formed, you need only think of the stars shaping themselves out of the cloudy arms of the nebulae. As I told you in the last Chapter, the particles in a nebulae tend to gather into knots, which

make stars. In the same way, the particles in the arm drawn from the sun would tend to gather into knots, so making the planets, of which our Earth is one.

But what about the planets' moons, and that queer bunch of fragments labelled "asteroids" in the diagram and sometimes called "minor planets"? And the shooting stars? And the comets?

These questions are not very difficult to answer. The planets' moons seem to have been formed very much in the same way as the planets themselves. When the planets were new they had not settled into the regular tracks they now follow round the sun. The disturbing visitor was still near enough to pull them about and bring them at times close enough for the sun to pull an arm out of them, and so provide stuff for moons.

Looked at in this way, Jupiter with its nine moons is a kind of model of the solar system, built not quite to the same pattern but by the same process.

It is not likely, however, that our particular Moon was formed in this way. Jupiter and Saturn are so huge that they might be expected to keep in the flaming-gas state for a long time. Our Earth, however, is so small, compared with Jupiter or Saturn, that it must have cooled from a gas to a liquid very quickly. When it was in the liquid state, the pull of the sun would draw out of it a big liquid blob, which, on cooling, would harden into a solid ball just like our moon.

The asteroids, which swarm in thousands between Mars and Jupiter, are supposed to have been originally a planet, which was broken up, probably by coming too near to Jupiter. Just as a strong pull will draw an arm of stuff out of a globe of gas, or a blob of liquid out of a liquid planet, so it may pull a solid planet to pieces. Jupiter is so enormous that it could easily shatter any planet that came within the danger zone.

Saturn's rings, by the way, seem to have been a moon in the first place—a moon

which was broken up into dust by coming too near the planet.

The shooting stars and the comets may be explained in the same way. They are the fragments left floating about when the solar system was in the making. They may be compared to the rags left over when cloth has been cut up to make a number of suits of clothes.

We have now come near the end of our quest. We have made a grand tour of the Heavens and have come back home to Earth, having learned, on the way, quite a lot about how that Earth was made.

If you are not too tired with your journey, you may feel ready to ask me a host of questions about all sorts of things. One you are most likely to ask is whether there are any other worlds like ours where people are living.

What there may be in the way of other worlds among the stars we, of course, do not know. They are far too far away for us to do anything but guess. The only

place we know where life is at all likely to exist is on our neighbour Mars. Mars has an atmosphere, which living creatures might breathe. It appears to be neither too hot nor too cold. Indeed, its conditions are so near to those on our world that some people have solemnly suggested that certain wireless signals received here have been sent by the people on Mars. They have also proposed that we should flash bright lights as a signal to our Martian cousins.

These things, however, belong to the world of fairy tales rather than of science. When we ask what science has to tell us of other worlds—meaning worlds that are fit for people like ourselves to live on—we get a very strange answer.

We depend on the sun for our very life. Without its light and warmth we and all other living things would die. Indeed, we cannot imagine living things being able to exist on anything but a cool planet which gets enough, and not too much, light and heat from a sun.

Now, planets, as Sir James Jeans reminds

us, "are very rare. They come into being as the result of the close approach of two stars, and stars are so sparsely scattered in space that it is an inconceivably rare event for one to pass near to a neighbour."

Again, even if among the stars there were some sun and planet systems like ours, the chances are that few planets, if any, would have just the conditions suited to life as we know it. As Sir James Jeans says, "millions of millions of stars exist which support no life, which have never done so and never will do so. Of the rare planetary systems in the sky, many must be entirely lifeless, and in others life, if it exists at all, is probably limited to a few planets."

Our little speck of a world, then, is something very special indeed. While it is made of the same stuff that we find as far as our telescopes and spectroscopes can reach, and while the laws that govern the spinning of the electrons in our atoms are the same as those controlling the wheeling of the giant nebulæ, we may be the only creatures in the universe who have made these discoveries.

Whether that is so or not, I think we are entitled to pat ourselves on the back for having found out so much in so short a time.

When you are learning history, you feel that it is a long long time since the Norman Conquest, or since the days of the ancient Romans and Greeks. It is, in a sense, a long time, and the time is longer still since the pre-historic days of the Stone Age. But, after all, it is only about 300,000 years since Man rose from the animal and became what we call Man. Life probably began on the earth about 300,000,000 years ago, and the Earth itself was born about 2,000,000,000 years ago. So Man's whole history, from its very beginning, is a mere nothing compared with the history of the world he lives on.

Again, it is only 300 years since the telescope was invented and Man set out, with its aid, to explore the heavens. In that short time we have learned more about the mysteries of the very little and the very great than were discovered in all the

previous thousands of years in which Man wondered about the why and how of things around him and inside him. We may well hope, therefore, that in the next hundred years we shall learn a tremendous lot more than we know to-day, and that many of the puzzles that still worry us will soon be solved.

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